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The SCIENTIFIC MONTHLY

January 1944

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PUBLISHED BY THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Smithsonian Institution Building, Washington 25, D. C.

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Relapsing Fever. 25 authors; 136 pages. 1942	2.50	3.00
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Man's Food: Its Rhyme or Reason. 223 pages. 1943	2.00	2.50

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The Bulletin is published monthly by the Association and is sent without charge to all members. To others, $1 per calendar year; 10 cents per copy.

For further information about the Association address the Office of the Permanent Secretary.

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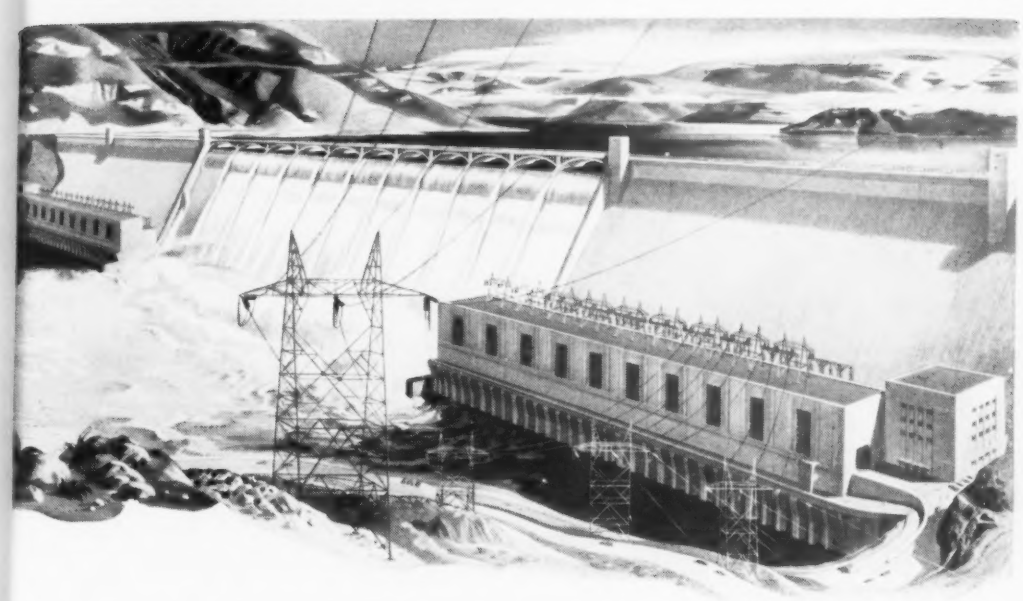

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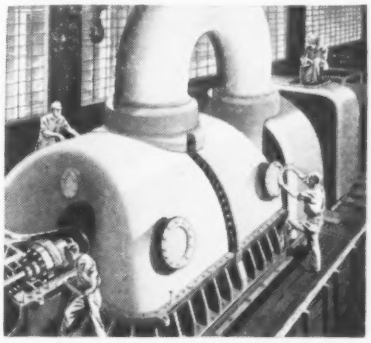

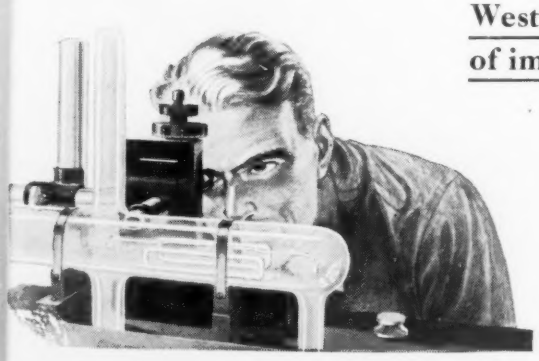

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Vol. LVIII, No. 1 **JANUARY, 1944** **Whole No. 340**

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THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

Founding and Organization

In 1848, on September 20, the Association was formally organized and held its first meeting; in 1874 it was incorporated under the laws of the Commonwealth of Massachusetts and given the right to receive, purchase, hold and convey property. Its governing body is a Council, now having 255 members.

The Association is national in scope, with membership open to the whole world on equal terms, and its interests include the broad fields of the natural and the social sciences. Its varied activities are carried on under 16 sections with which 187 affiliated societies, having a combined membership of nearly a million, cooperate in organizing programs for its meetings.

Members and Meetings

All persons engaged in scientific work, all who find pleasure in following scientific discoveries, all who believe that through the natural and social sciences a better society may be achieved are eligible for membership in the Association. From its founding the most distinguished of American scientists, including every American Nobel Laureate in science and every president of the National Academy of Science, have been members. The names of many university presidents, of eminent scholars in widely different fields, and of men notable for public service, including a United States Senator, a Justice of the Supreme Court, and a former president of the United States, are now on its roll of nearly 25,000 members.

The Association's meetings are field days of science attended by thousands of participants and spectators at which hundreds vie with one another for the pleasure and the honor of presenting results of researches of the greatest benefit to their fellow men. An enlightened daily press reports their proceedings throughout the country.

Opportunity and Responsibility

A world torn by conflicts and fearful of the future is looking more and more toward scientists for leadership. The opportunity for unparalleled service is theirs and the fact that they have available the only essentially new methods, if not purposes, imposes an equal responsibility. For these reasons it will be the Association's steadfast purpose to promote closer relations among the natural and the social scientists, and between all scientists and other persons with similar aspirations, to the end that they together may discover means of attaining an orderliness in human relations comparable to that which they find in the natural world about them.

MEET THE AUTHORS

EDWIN R. GILLILAND, Sc.D., is Assistant Rubber Director in charge of Research and Development for the Government synthetic rubber program. He came to the War Production Board, Washington, D. C., on leave of absence from the Massachusetts Institute of Technology at which he was Associate Professor of Chemical Engineering. Dr. Gilliland was born in Oklahoma in 1909, took his undergraduate work at the University of Illinois, his master's degree at Pennsylvania State College, and his doctorate at the Massachusetts Institute of Technology.

ALBERT F. KUNZE, LL.B., was born in Jersey City, N. J., in 1891. Later a resident of Chicago, he studied at The University of Chicago and Northwestern University. He served in the Infantry in World War I and after the war he became an attorney for the Government, first on the termination of war contracts and then as Counsel before the U. S.-Mexican General and Special Claims Commission. Stamp collecting, once a hobby, became his vocation in 1940 when he took charge of the newly created Philatelic Section of the Pan American Union (below) in Washington, D. C. His activities are now directed toward increasing public interest in the cultural, historical, and economic phases of the Latin American Republics through the designs selected by them for the decoration of their postage stamps. Mr. Kunze points out that the stamps illustrating his present article on the Amazon were issued in 1943, although the quadricentennial of the discovery of the great river, which they commemorate, occurred in 1942.

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$2.75 — By PASTOR MARTIN NIEMOELLER, being a collection of his last sermons which were taken down in shorthand and secretly distributed in Germany. It is from one of these copies that the present translation has been made. With a preface by Thomas Mann.

Encyclopedia of Child Guidance
$7.50 — Edited by RALPH B. WINN. This volume, a work of collaboration of eminent educators and physicians deals with all phases of child guidance, and its many ramifications. A book of enormous practical value to every person and group concerned with the training and development of children.

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NEW BOOKS

Twentieth Century Philosophy. Edited by D. D. RUNES. 571 pp. 1943. $5.00. Philosophical Library.

The editor has assembled twenty-two essays by outstanding present-day thinkers in an effort to review broadly the philosophical trends current in the world. Representatives of various conflicting schools and movements are included. The book begins with an essay on ethics by the late James H. Tufts.

Plants and Vitamins. W. H. SCHOPFER. Translated by N. L. NOEKER. Ill. xiv + 293 pp. 1943. $4.75. Chronica Botanica.

The author of this important work on vitamins in the light of general physiology is director of the Botanical Institute, University of Bern. The book demonstrates that "the loss of capacity to synthesize vitamins by a plant leads it to the same level as that occupied by an animal."

Food and Farming in Post-War Europe. P. L. YATES and D. WARRINER. Ill. v + 118 pp. Sept., 1943. $1.25. Oxford.

An Oxford pamphlet on world affairs, this little book takes up the gigantic problems concerning the post-war welfare of Europe's peasantry and points out, with factual data, the urgent need of a vast program to raise the standards of the cultivators of the old world.

Drying and Dehydration of Foods. H. W. VON LOESECKE. Ill. 302 pp. Aug., 1943. $4.25. Reinhold.

This is a descriptive outline of the procedure and practices concerned with a relatively new large-scale industry in this country. The authoritative writer is a research chemist of the Dehydration Committee of the Bureau of Agricultural Chemistry and Engineering, U. S. Department of Agriculture.

Electricity. CHARLES A. RINDE. Ill. xii + 466 pp. 1943. $2.50. Harcourt, Brace.

This book is organized around the War Department's outline, *Fundamentals of Electricity;* it carries the uninitiated through detailed explanations of electrical devices and their application to civilian and military life. Its central theme is the control of electrons in this age of electricity.

Burma Surgeon. GORDON S. SEAGRAVE. Ill. 295 pp. 1943. $3.00. Norton.

A medical missionary, who practiced in the North Shan States from 1922 until he became a Lieutenant Colonel of the U. S. Army when the war broke over Burma, relates the stirring story of the heroic retreat with General Stilwell through the terrible jungle to India.

The American-Born in Canada. R. H. COATS and M. C. MACLEAN. xviii + 176 pp. 1943. $3.75. Ryerson.

One of a series of three studies on Canadian-American migration, this book by two eminent Canadian statisticians presents a statistical interpretation of the substantial migrations made across the border in both directions. The United States, according to the 1931 census, was second contributor of immigrants into Canada, England being first.

Man's Food: Its Rhyme or Reason. MARK GRAUBARD. x + 213 pp. Nov., 1943. $2.50. Macmillan.

The attitudes of man toward food throughout the ages are vividly described, analyzed and illustrated to show that food habits are primarily psychological rather than biological. The nutritional value of various foods and the need for dietary education to combat harmful traditional food habits are also discussed.

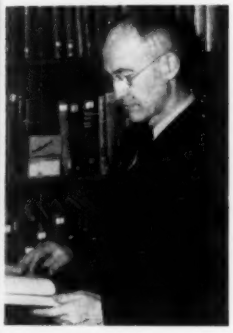
MEET THE AUTHORS, Continued

C. K. TSENG (Tseng, Cheng-kwei), Sc.D., has two addresses: Department of Botany, University of Michigan and The Scripps Institution of Oceanography, La Jolla, California. His present article is a contribution from the latter Institution, where he is engaged in research on seaweeds. Dr. Tseng was born in Fukien Province, China, in 1909. He received his education at the University of Amoy, Lingnan University, and the University of Michigan. He taught at three Chinese universities, finally becoming Assistant Professor of Botany at Lingnan in Hong Kong. From 1930 to 1940, he made several collecting trips along the China coast to investigate the seaweed resources of his country and now has perhaps the largest collection of Chinese seaweeds in the world. He believes that the value of seaweed resources has been neglected in most countries and that man could derive much more food and industrial raw materials from marine vegetation than he is now obtaining.

J. O. PERRINE, Ph.D., is Assistant Vice President of the American Telephone and Telegraph Company, New York City. Bushnell, Illinois, was his birthplace in 1886. He studied at Iowa, Michigan, and Cornell Universities, taught at Iowa State Teachers College, Yale, and Cornell and has been with A. T. & T. since 1921. During World War I he was a Captain in the Signal Corps. Dr. Perrine is an all-round man, skilled not only in electrical communications, but in athletics, writing, and public speaking. He has played and coached football and basketball and now bowls and plays tennis. He is an editor of The Bell System Technical Journal. In 1928 and 1930 Dr. Perrine gave the de Forest lecture in communication at Yale. During recent years he has given a number of scientific lectures and demonstrations on electrical communications before colleges, engineering societies, and civic clubs in the United States and Canada.

MEET THE AUTHORS, Continued

COMMANDER ELLIS HERNDON HUDSON, M.D., was Director of Health and Professor of Hygiene at Ohio University, Athens, Ohio, when he was called to active service in the Navy, in Hawaii, early in 1942. Now he is in charge of Tropical Disease Service, Naval Hospital, Bethesda, Maryland. Dr. Hudson's extensive foreign experience began early. He was born and brought up in Japan, received his bachelor's degree at Millikin University and his medical training at the University of Pennsylvania (M.D. 1919). He then spent sixteen years in the Near East; four at the American University at Beirut and twelve in medical work at Dier-ez-Zor, Syria, where he organized the Presbyterian Medical Center for Bedouins of the Euphrates region. He capped his formal training at the London School of Hygiene and Tropical Medicine in 1936. He has published many articles on diseases of the Arabs. He believes that more attention should be given to tropical medicine in our medical schools. He enjoys music, tennis, and golf.



GEORGE D. BIRKHOFF, Ph.D., Sc.D., hon. Dr., LL.D., is Perkins Professor of Mathematics at Harvard University. Professor Birkhoff is a Captain of Science, in the sense that Henry J. Kaiser is a Captain of Industry. The reader should see *Who's Who in America* for the facts of his distinguished career. He was born in Overisel, Michigan, in 1884, grew up in Chicago, studied at Harvard, and took his doctorate at The University of Chicago. Although he did not go abroad until 1926, he has travelled extensively in Europe. He has visited the Far East twice. While visiting Mexico in 1942, he formulated a new theory of gravitation mentioned in his present article. He is now in Mexico again for a period of four months. He likes to meet his foreign colleagues, firmly believes that international cooperation will become extensive, and thinks that pure science affords an ideal starting point for cooperation.

NEW BOOKS

Galaxies. HARLOW SHAPLEY. Ill. vii + 299 pp. 1943. $2.50. Blakiston.

Much original information is contained in this clearly written, well-illustrated work by one of America's outstanding astronomers. Topics range from the Milky Way to the boundaries of measured space, including discussions on the tools of measurement and comprehension, on single stars, groups of stars, the Metagalaxy, and the expanding universe.

The Psychology of Jung. JOLAN JACOBI. Ill. xi + 166 pp. Nov., 1943. $2.50. Yale.

The author, who has worked closely with Jung, has prepared a guide to the renowned psychologist's voluminous works and a shortcut to the understanding of his ideas. Her book has the sanction of Jung who contributes the foreword in which he maintains that his is not a dogmatic system.

Garden Islands of the Great East. DAVID FAIRCHILD. Ill. xiv + 239 pp. Oct., 1943. Scribner's.

The author of *The World Was My Garden* describes another journey to collect new plants for the gardens of America. Traveling in a Chinese Junk, his party gathered seeds in the Philippines and Netherlands India. The book includes many rare and beautiful photographs taken by the author and Edward Beckwith.

Man in the Air. HERBERT S. ZIM. Ill. x + 332 pp. 1943. $3.00. Harcourt, Brace.

Dr. Zim furnished an introduction to aviation medicine in his book on the effects of flying on the human body. The effects of high altitudes, low temperature, increased speed, and sudden changes on the heart, lungs, blood, eyes, ears, etc., are reviewed in the light of the lessons of the present war.

Handbook of Salamanders. SHERMAN C. BISHOP. Ill. xiv + 555 pp. 1943. $5.00. Comstock.

Species and subspecies, a total of 126, of salamanders native to the United States, Canada, and Lower California are described and fully illustrated in this extensive work by a professor of vertebrate zoology at the University of Rochester. A bibliography covering 67 pages is included.

Tungsten. K. C. LI and C. Y. WANG. xvii + 325 pp. Sept., 1943. $7.00. Reinhold.

K. C. Li, one of the co-authors of this American Chemical Society monograph, was the chance discoverer in 1911 of the world's greatest source of this vital ore in Southwest China. The book takes up the history, geology, ore dressing, metallurgy, chemistry, analysis, industrial application, substitution, and economics of tungsten.

Introductory Animal Husbandry. ARTHUR L. ANDERSON. Ill. x + 777 pp. 1943. $4.00. Macmillan.

This comprehensive textbook for college students of animal husbandry takes up types of livestock, markets, market classification, prices, feeding, management and breeding; shows the effects of farm mechanization, changes in marketing of livestock and merchandising of animal products; and supplies current data on outlook reports and market reports.

AEROBIOLOGY

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This volume, one of the Symposia Series, consists of 37 papers. Eight papers cover *extramural aerobiology* which is concerned with the distribution of living organisms by the exterior air and with some of the consequences of their distribution. Twenty-nine papers on *intramural aerobiology* cover (1) the problem of contagion by air-borne infectious materials, (2) expulsion of secretions from the mouth and nose, and (3) infections from dissemination of pathogenic organisms into the operating room, the hospital ward, the school and the home. Published in 1942. $4.00. $4.00.

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in Studies of

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Another of the Symposia Series, containing 12 principal papers and 41 supplementary contributions on (1) rearing test insects, (2) rearing insects that attack stored products, (3) rearing insects affecting man and animals, (4) methods of testing insecticides against insects in the laboratory, and (5) statistical methods. Bibliography of 500 references. Two indexes, one of scientific names and the other of common names of insects. Published in 1943. $4.00.

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MEET THE AUTHORS, Continued

M. F. ASHLEY MONTAGU, Ph.D., is Associate Professor of Anatomy at the Hahnemann Medical College and Hospital, Philadelphia, Associate Editor of *Isis* (the international journal of the history of science), and an officer of the History of Science Society. He was born in London, England, in 1905 and was educated at the Universities of London, Cambridge, and Florence, abroad, and at Columbia in New York. Dr. Montagu is a student of man, working principally in the field of physical anthropology, but he has also delved into cultural anthropology, social biology, anatomy and the history of science, as shown by three books published by him since 1938 on Australian aborigines, fallacy of race, and Edward Tyson, a British anatomist. He does a good deal of writing for the general public also, believing that scientists should participate in popular education. Somehow he finds time for book collecting, reading, gardening, playing with his three children, and "working out new methods of changing and washing diapers."

KARL SAX, Sc.D., is the spiritual successor at Harvard of E. M. East (*Mankind at the Crossroads*); by title he is Professor of Botany. He was born in Spokane in 1892. His work in western harvest fields and orchards led him to Washington State College where he decided to become a plant breeder. After World War I, in which he served as second lieutenant in the Canal Zone, he took his doctorate at that scientific monastery, the late Bussey Institution of Harvard. Before his return to Harvard in 1928, most of his work was done at the Maine Agricultural Experiment Station. Now he is engaged in cytological research and teaching in winter and spends the rest of the year developing new types of ornamental trees and shrubs, and species hybrids of forest trees.

STEPHEN S. VISHER, Ph.D., is Professor of Geography at Indiana University, Bloomington. See *Who's Who in America* for details.

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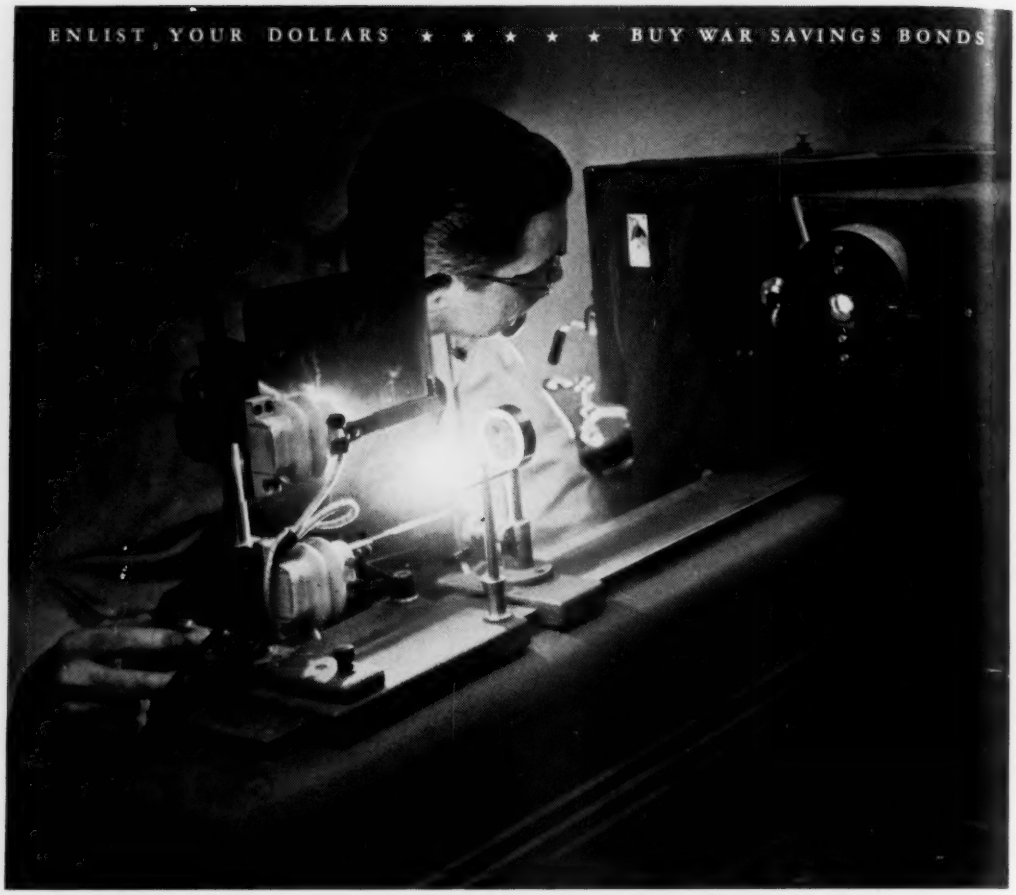

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THE SCIENTIFIC MONTHLY

JANUARY, 1944

SYNTHETIC RUBBER

By E. R. GILLILAND

By occupying the Malay Peninsula and the islands of the southwest Pacific Ocean, the Japanese precipitated a serious problem for this country because most of its rubber has come from that region. Directly or indirectly, rubber vitally affects nearly every aspect of our lives. To have the source of its supply suddenly cut off was almost disastrous.

It was very fortunate that an extended research and development program on making rubber or a material having similar physical and chemical properties had been carried on by scientists of various educational and commercial institutions. The development of new rubber plantations requires several years even when suitable tropical areas are available. The tropical areas of Central and South America are not well adapted to the development of such plantations because of certain plant diseases that, in those areas, attack the present type of rubber trees. It is probable that trees resistant to those diseases can be developed, but such a program would require a long experimental period.

I

English and German chemists were the first to attempt to make rubber—true rubber, not some other substance having similar properties. In order to make a chemical compound the first step normally is to find the chemical elements—oxygen, hydrogen, carbon, etc.—of which it is composed. But this is not enough. It is necessary also to find how the elements are joined together. There are common examples of chemical compounds that are composed of precisely equal numbers of the same atoms, but which differ greatly in their properties.

The English and German chemists who were working on natural rubber easily found its constituent elements and concluded that those elements were joined together into a chemical compound called "isoprene," or groups of isoprene molecules linked together. At least, by suitable chemical treatment, natural rubber can be broken down to isoprene or to chains of isoprene molecules. It is likely, if not certain, that rubber owes its remarkable properties to long chains of molecules formed by the joining of isoprene or similar units. When a molecule joins with similar molecules to form a chain, the process is called polymerization. This type of reaction has become of primary importance, not only in the production of rubber but also throughout the petroleum and plastic industries and elsewhere in industrial chemistry.

A large amount of experimental work was carried out on the polymerization of isoprene. None of these experiments resulted in polymers having properties the same as those of natural rubber. This is not surprising when one considers the large number of ways in which isoprene can combine with itself. In fact, there are natural substances which can be considered polymers of isoprene just as much as rubber is, but which have considerably different characteristics; gutta-percha is one example.

This experimental work on the polymerization of isoprene was carried out in a period when the cost of rubber was high and before plantation rubber had really been developed. With the lowering of the cost of rubber, the incentive to develop such materials became

less. Another deterrent has been the difficult problem of obtaining isoprene of high purity. Isoprene can be produced by high temperature cracking of turpentine and, in very low yields, by high temperature cracking of petroleum compounds, but both processes give products that require further purification—a rather difficult problem.

Following this period, the emphasis has shifted almost completely from attempts to produce true rubber by synthetic processes to attempts to produce materials that have properties similar to those of natural rubber and which can be produced from easily obtainable raw materials. These rubber-like materials have inherited the appellation "synthetic rubber," and this term has become a generic name for the whole group.

In the "crude" state a good rubber-like material can be easily worked, molded and shaped, and then can be changed chemically into a strong, elastic material that will resist deformation. As a result of intensive studies, chemists concluded that those organic materials having elastic properties are composed of very long, thin molecules. The ratio of length to diameter of a fully extended molecule may be as great as several thousand to one. Such molecules in the unvulcanized, or uncured, form of rubber are presumably greatly contracted in length and interwoven with one another. When a mass of such material is molded or shaped by being subjected to pressure or stretching, its individual molecules are actually displaced relative to one another. If then, by chemical processes, these long chain molecules can be tied together, further displacement relative to one another becomes much more difficult and the material acquires the property of resisting forces that otherwise would cause permanent deformation. However, owing to the contracted condition of the molecules, the material can still be extended. In this process the molecules are simply pulled out somewhat like a spring without causing their rearrangement.

In natural rubber the vulcanizing, or knitting together, of the rubber structure is generally carried out by the addition of sulfur, although in special cases oxygen is used. The mechanism of this process is not definitely known, but it is believed that the chemically unsaturated rubber molecules combine with other molecules or atoms, such as sulfur, and form some type of bridge or connection between adjacent rubber molecules.

The chemists, therefore, directed their studies to the production of long chain molecules that have this unsaturation characteristic and that can be locked together by vulcanization or an equivalent process. In general, chemical substances that are readily available or that can be prepared easily, economically, and in high purity are low in molecular weight, but only those capable of combining to form long chains are useful for the production of rubber-like substances.

The class of compounds that most nearly fits these two requirements of combining to form long chains and of having residual chemical properties suitable for vulcanization are the diolefins. Olefin is a generic name for certain compounds of hydrogen and carbon that, because they are unsaturated, combine more or less easily with other materials. A diolefin has two groups having the olefin characteristic in the same molecule. One of these unsaturated groups can be employed to combine with other molecules to form the long chains, leaving the other unsaturated group for use in the cross-locking of molecules in the vulcanization step. The diolefin group comprises a large number of chemical compounds, but only a relatively few of them can be prepared easily and economically on a large scale. Isoprene is a member of the diolefin class which contains five carbon atoms to a molecule, but, as has been pointed out, this particular compound is somewhat difficult to prepare. Of all the diolefins, butadiene is perhaps the easiest to prepare, and for that reason has become the basic raw material of most of the current synthetic rubber production. It has four carbon atoms and six hydrogen atoms to the molecule. Another diolefin that is employed in the present Government program is chloroprene, a chlorinated butadiene. Dimethyl butadiene was employed by the Germans during World War I to prepare the so-called methyl rubber.

Butadiene can be polymerized in a number of ways, but for most uses it has been found advantageous to copolymerize it with other

organic molecules, such as styrene, acrylonitrile and the various acrylates. These materials can be made to react with butadiene during the polymerization, or chain forming, process. In other words, the long chain molecule is composed of a mixture of the two types of molecules, probably somewhat irregularly spaced. The addition of these materials gives an improved synthetic rubber often possessing very desirable special properties.

II

The United States Government program includes the production of three types of synthetic rubber—Buna-S, Butyl, and Neoprene. For this program the products have been named GR-S, GR-I, and GR-M, respectively.

The annual rated capacities in long tons (2,240 pounds) of the rubber plants constructed and under construction in the United States and Canada are as follows:

GR-S	735,000
GR-I	75,000
GR-M	40,000

In addition, the annual production of privately owned plants will be as follows:

Neoprene	9,000
Buna-N	24,000

Production of GR-S (Buna-S)

GR-S is the main synthetic rubber of the United States and Canadian programs. Plants under construction have a rated capacity when complete of 735,000 long tons per year, which is 86 percent of the expected total. GR-S is a copolymer of butadiene and styrene and was chosen because it is a general purpose rubber that can replace natural rubber in most uses.

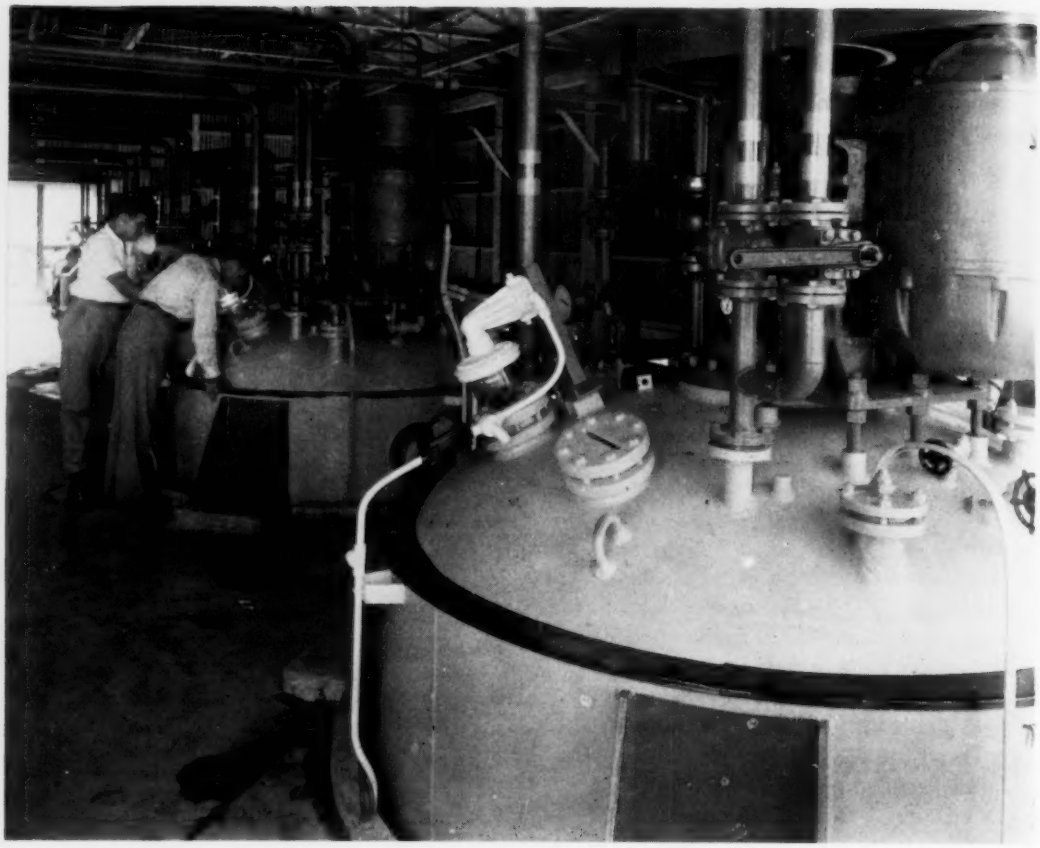
Preparation of Raw Materials. Butadiene, which constitutes the largest tonnage of raw material employed in the Government synthetic program, can be prepared from a large number of substances in a number of different ways. Actually, it is being made from each of the following four products: ethyl alcohol, butylene, butane, and gasoline and heavier petroleum products.

The reactants concerned in the first three cases are treated catalytically at relatively high temperatures and low pressures, and they give high yields of butadiene relative to the quantity of the starting material. Production from gasoline and oil requires a high temperature, low pressure thermal treatment in which the larger molecules are broken up with the production of a small percentage of butadiene and large quantities of other materials.

In the alcohol process, grain alcohol or ethyl alcohol from other sources is used to produce a butadiene fraction of relatively high purity. The equipment necessary for concentrating this fraction to high purity butadiene is relatively simple. This type of operation is carried out in three plants designed for the Government program by the Carbide and Carbon Chemical Corporation. These plants will produce 220,000 short tons of butadiene per year. The first, located at Institute, West Virginia, and having a rated annual capacity of 80,000 short tons has been completed for several months and is operating very successfully. The two other plants, located at Kobuta, Pennsylvania, and Louisville, Kentucky, and having rated annual capacities of 80,000 and 60,000 short tons, respectively, are now producing butadiene. The plants at Institute and Louisville are operated for the Government by the Carbide and Carbon Chemical Corporation, and the plant at Kobuta is operated by the Koppers-United Company.

A different type of process for producing butadiene from alcohol is being constructed by the Bigler Chemical Company, employing the so-called Publicker, or Szukiewicz, process. This alcohol process apparently is fairly similar to the method employed by the Russians for the production of essentially all their butadiene.

These alcohol processes produce from two to two and a half pounds of butadiene per gallon of 95 percent alcohol. In general, about 2.7 gallons of such alcohol can be produced per bushel of corn. In other words, one bushel of corn will produce between 5.5 and 6.8 pounds of butadiene. Therefore, by this type of operation, even high quality farm land would produce only enough grain per acre, per year, to make butadiene equivalent to approximately 350 pounds of synthetic rubber, which is substantially less than the 450 pounds of natural rubber that can be



TOP VIEW OF THE REACTORS IN THE STANDARD GR-S PLANT

produced per acre in the tropics. If wheat is employed for the production of butadiene, the quantity that can be produced per acre is only about one-third that obtainable from corn, but the percentage of the farm land of the United States suitable for wheat production is much greater than that for corn.

The plants employing the process for producing butadiene from butylenes have a total annual rated capacity of 292,000 short tons. The normal butylenes employed are a by-product of the refinery operations, such as catalytic and thermal cracking. Normal butylene differs from butadiene only in having two more hydrogen atoms per molecule. The procedure involves the removal of these two extra atoms by a process called dehydrogenation. The operation is carried out by contacting butylenes with a catalyst at high temperature. A portion of the butylenes is converted to butadiene, which is then removed and purified, while the unreacted

TABLE 1. PLANTS SCHEDULED FOR THE PRODUCTION OF BUTADIENE FROM BUTYLENES

Operating company	*Location*	*Annual capacity*
Standard Oil Co. of Louisiana	Baton Rouge, La.	15,000
Humble Oil & Refining Co.	Baytown, Tex.	30,000
Shell Chemical Co.	Torrance, Calif.	12,000
Neches Butane Products Co.	Port Neches, Tex.	100,000
Sinclair Rubber, Inc.	Houston, Tex.	50,000
Polymer Ltd.	Sarnia, Canada	30,000
Cities Service Refining Corp.	Lake Charles, La.	55,000
		292,000

butylenes are recycled for further conversion. Such a process produces about 2.7 pounds of butadiene per gallon of butylene.

The butylene dehydrogenation process, which will be used in seven plants scheduled for the United States and Canada, was developed by the Standard Oil Company of New Jersey. Table 1 lists the companies that will operate the plants for the Government,* together with their locations and annual rated capacities in short tons (2,000 pounds).

The plants at Baton Rouge and Baytown are in operation, and construction of most of the others is nearing completion.

The process for preparing butadiene from butane is somewhat similar to that employing butylene. Butane differs from butadiene in containing four more atoms of hydrogen per molecule, and it is, therefore, necessary to remove twice as much hydrogen as is necessary with butylene. The actual process is carried out similarly by a catalytic dehydrogenation operation at high temperatures involving either a one-stage or a two-stage process. In the one-stage operation a mixture of butane and butylene is passed over the catalyst and a portion is dehydrogenated to butadiene, while simultaneously a portion of the butane is converted to butylene. The butadiene is removed and concentrated, and the mixture of butylene and butane is recycled for further treatment with the addition of make-up butane. In the two-stage process, butane is dehydrogenated to butylene, which is separated from the unreacted butane and then further dehydrogenated to butadiene. The unreacted butane and butylenes are recycled in their respective steps.

The Government has scheduled a production of 75,000 short tons of butadiene a year by the butane process. Two plants are employing the so-called one-stage method, known as the Houdry process. Both have annual rated capacities of 15,000 short tons of butadiene. One of the plants will be operated by the Sun Oil Company at Toledo, Ohio, and the other by the Standard Oil Company of California at El Segundo, California. A plant employing the two-stage process is being operated by the Phillips Petroleum Company at Borger, Texas. This unit has an annual rated capacity of 45,000 short tons of butadiene.

This type of operation produces about two pounds of butadiene per gallon of normal butane. While the yields per gallon are lower than from butylene, normal butane is a raw material that is more available, being a constituent of the natural gas produced in various parts of the United States.

The production of butadiene from gasoline and heavier petroleum fractions differs from the foregoing processes because butadiene is a relatively minor fraction of the total output. This thermal cracking process seldom produces more than six percent, by weight, of butadiene from the material charged. Besides butadiene, this method produces a large number of other valuable products, such as ethylene, propylene, butylenes, isoprene, piperylene, benzene, toluene, xylene, lighter gases and heavier residuals. If an integrated plant can be built to utilize a number of these by-products, this method will furnish a desirable process for the production of butadiene. If the by-products are not efficiently utilized, the process is feasible only as an emergency operation.

The petroleum fractions are vaporized and then treated at high temperatures either in a tubular furnace or in a regenerative type brick-work. The products, which contain

TABLE 2. PLANTS SCHEDULED FOR THE PRODUCTION OF BUTADIENE FROM PETROLEUM

Operating Company	*Location*	*Annual capacity*
Southern Calif. Gas Co.-Shell Chemical Co.	Los Angeles Torrance, Cal.	30,000
Standard Oil Co. of Louisiana	Baton Rouge, La.	6,800
Eastern States Petroleum Co.	Houston, Tex.	12,800
Humble Oil & Refining Co.	Ingleside, Tex.	7,000
Lion Oil & Refining Co.	El Dorado, Ark.	6,700
Taylor Oil & Refining Co.	Corpus Christi, Tex.	5,500
		68,800

* The Polymer Ltd. plant of Sarnia, Canada, included in some of these tables, is not a part of the United States Government program.

GOVERNMENT OWNED BUTADIENE PLANT OPERATED BY HUMBLE OIL, BAYTOWN, TEXAS

materials ranging from light gases to heavy hydrocarbons, are cooled and then fractionated to produce a narrow boiling fraction containing the butadiene. This is then treated for the recovery of the diolefin. Six plants have been scheduled for the Government program. The companies operating, their locations, and annual capacities in short tons are shown in Table 2.

In addition to the Government plants, there are six butadiene plants that are privately owned and operated. These plants are all in operation and have a combined annual production of approximately 25,000 short tons of butadiene.

When all plants, both private and government owned, are operating at capacity, the total butadiene production of the United States and Canada will be in excess of 690,000 short tons per year.

In the absence of sufficient information, consideration of the relative merits of the processes based on petroleum raw materials and of those based on alcohol has led to heated discussions. At the present time both processes have operated long enough to clarify the matter. It appears that there will not be any very great difference in the capital investment per ton of capacity of the two types of plants, including the necessary auxiliaries for the production of the feed materials, and that the operating costs per pound of butadiene will be about the same for the various processes. It becomes, therefore, largely a matter of the relative cost of the raw materials employed and the value of the by-products produced. As indicated above, the petroleum processes will produce about 2.7 pounds of butadiene per gallon of butylene, or 2 pounds per gallon of butane, while a gallon of alcohol will produce from 2 to 2.5 pounds of butadiene. As far as initial feed stocks are concerned, it thus appears that the price of alcohol per gallon

should not greatly exceed the corresponding price of butane or butylene if the processes are to be competitive. Actually, the price of alcohol has been much higher than the cost of these hydrocarbons. On the other hand, the alcohol process produces certain valuable by-products, whereas the butane and butylene processes have only a waste gas as a by-product. Even with the credit for these by-products, it does not appear that alcohol can be produced from grain, at the prices that have prevailed over the past five years, at a cost low enough to be really competitive with the petroleum butadiene operations. However, alcohol produced from molasses or synthetic alcohol produced from ethylene could probably compete with butane and butylene as a raw material for butadiene production.

Actually, it has been possible to construct the alcohol butadiene plants and to bring them into operation appreciably faster than the petroleum butadiene units. At the present time a high percentage of the butadiene is being produced by the alcohol operations, and it will be several months before the production of the petroleum plants exceeds that of the alcohol units.

FRACTIONATORS, BUTADIENE PLANT
OPERATED BY PHILLIPS PETROLEUM CO., BORGER, TEXAS

Styrene constitutes the other main ingredient of GR-S. It is prepared by combining ethylene with benzene to form ethylbenzene. This operation is carried out at moderate temperatures in the presence of a catalyst. Most of the benzene employed is a by-product fraction obtained in the coking of coal, and the ethylene employed is produced either from ethyl alcohol or by cracking of petroleum products.

The ethylbenzene so obtained differs from styrene in the same way that butylene differs from butadiene; namely, it contains two more hydrogen atoms per molecule. Dehydrogenation of ethylbenzene to styrene is very similar to the dehydrogenation of butylene to butadiene. In this case the crude mixture obtained by the dehydrogenation reaction is separated by fractional distillation, and the unreacted ethylbenzene is then recycled for further reaction. Six styrene plants were scheduled in the Government program. The companies operating, and the locations and short ton capacities of their plants are shown in Table 3.

TABLE 3. PLANTS SCHEDULED FOR THE PRODUCTION OF STYRENE

Operating company	*Location*	*Annual capacity*
Monsanto Chemical Co.	Texas City, Tex.	50,000
Dow Chemical Co.	Los Angeles, Cal.	25,000
Carbide & Carbon Chemical Corp.	Institute, W. Va.	25,000
Polymer Ltd. (Dow)	Sarnia, Canada	10,000
Koppers-United Corp.	Kobuta, Pa.	37,500
Dow Chemical Co.	Velasco, Tex.	50,000
		197,500

All these plants are now in full or partial operation, and the processes appear to be satisfactory. In addition to the above Government owned plants, there is a private plant of the Dow Chemical Company at Midland, Michigan, which has been expanded during the present emergency. A large portion of the production of this private plant has been employed for the production of GR-S during the present year (1943).

Polymerization. Butadiene and styrene can be polymerized in various ratios and in a number of ways. The process selected for

the Government program involves the use of about 3.5 parts by weight of butadiene for each part of styrene. The actual polymerization is carried out by emulsifying the butadiene and styrene with an aqueous solution of the other chemical ingredients, and during the reaction period of between ten and twenty hours, about three-fourths of the butadiene and styrene are converted to the rubber-like material. In other words, the emulsified droplets of the liquified hydrocarbons are converted to small particles of solid rubber. When the reaction has proceeded to the desired degree, the unreacted butadiene and styrene are removed and recycled to succeeding batches. In this way a GR-S latex is obtained that is very similar in appearance to natural rubber latex. In other words, it is a milky suspension of the rubber particles. It can be used as a latex for certain dipping processes or it can be coagulated and the aqueous medium separated by filtration. After drying, the rubber crumbs can be baled or sheeted and then handled on the usual rubber fabricating facilities.

TABLE 4. PLANTS SCHEDULED FOR THE PRODUCTION OF GR-S (BUNA-S)

Operating company	*Location*	*Annual capacity*
Firestone Tire & Rubber Co.	Akron, O.	30,000
Goodyear Tire & Rubber Co.	Akron, O.	30,000
U. S. Rubber Co.	Naugatuck, Conn.	30,000
B. F. Goodrich Co.	Louisville, Ky.	45,000
U. S. Rubber Co.	Institute, W. Va.	90,000
Copolymer Corp.	Baton Rouge, La.	30,000
Goodyear Tire & Rubber Co.	Los Angeles, Cal.	60,000
B. F. Goodrich Co.	Louisville, Ky.	15,000
B. F. Goodrich Co.	Borger, Tex.	45,000
General Tire & Rubber Co.	Baytown, Tex.	30,000
B. F. Goodrich Co.	Port Neches, Tex.	60,000
National Synthetics	Louisville, Ky.	30,000
Polymer Corp., Ltd.	Sarnia, Canada	30,000
U. S. Rubber Co.	Los Angeles, Cal.	30,000
Firestone Tire & Rubber Co.	Port Neches, Tex.	60,000
Goodyear Tire & Rubber Co.	Houston, Tex.	60,000
Firestone Tire & Rubber Co.	Lake Charles, La.	60,000
		735,000

Production of GR-S. The Government program contemplates seventeen plants for the production of GR-S. The companies operating, and the locations and long ton capacities are shown in Table 4.

At the present time sixteen of these seventeen plants are in operation.

PRODUCTION OF GR-I (BUTYL)

Butyl rubber is scheduled to be produced at the rate of 75,000 tons per year when the plants are in operation at rated capacities. Three plants included in the Government program (capacities in long tons) are listed in Table 5.

The Baton Rouge plant has begun operation and the two others are still under construction.

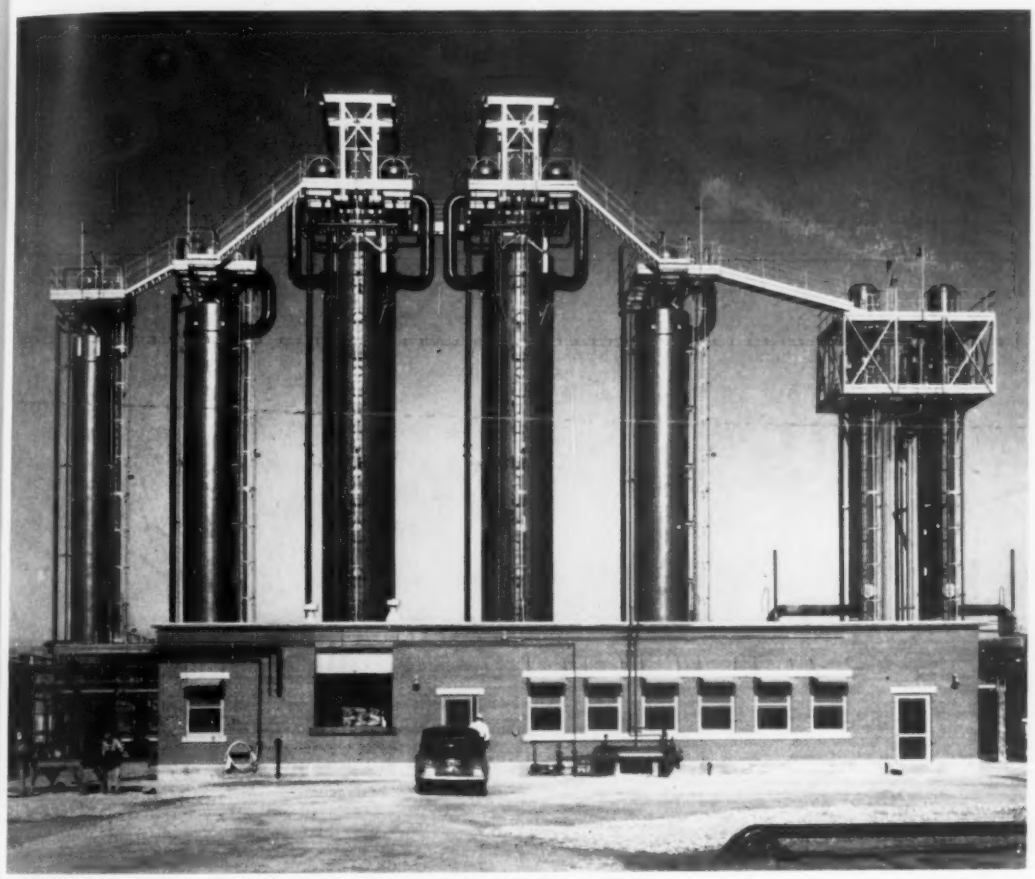
TABLE 5. PLANTS SCHEDULED FOR THE PRODUCTION OF GR-I (BUTYL RUBBER)

Operating company	*Location*	*Annual capacity*
Standard Oil Co. of Louisiana	Baton Rouge, La.	38,000
Humble Oil & Refining Co.	Baytown, Tex.	30,000
Polymer Corp., Ltd.	Sarnia, Canada	7,000
		75,000

Raw Materials. Butyl rubber consists of from 96 percent to 99 percent isobutylene. Isobutylene is a low molecular weight hydrocarbon containing four carbon atoms to a molecule and having a single olefinic unsaturation. In the presence of the proper catalyst and under the proper conditions of temperature and pressure, it has the property of being polymerizable to an extremely high molecular weight, long chain compound. In doing so the olefinic bonds of the isobutylene molecules are used in joining other iso-

butylene molecules to form the chain. It results, therefore, in a material which is rubber-like but which does not contain the residual chemical unsaturation necessary for vulcanization. Isobutylene polymerized in this form is called Vistanex, or polyisobutylene, and has a considerable use as a rubber-like material. It is made vulcanizable by copolymerizing a small amount of diolefinic material, such as butadiene, isoprene or other diolefins, with the isobutylene. The addition of the diolefin leaves an unsaturation in the polymerized molecule that can be utilized for vulcanization. While other diolefins can be employed, the present GR-I program contemplates using a few percent of isoprene as the diolefinic material. Isobutylene is a by-product of the cracking of petroleum fractions, and it is concentrated by a series of extraction and fractionating steps to the high purity necessary for the butyl rubber reaction.

Isoprene is to be obtained from two sources: first, from thermal decomposition of turpentine and, second, as the by-product of butadiene production. The second source is related to the thermal cracking of gasoline and heavier petroleum fractions for the production of butadiene. In this cracking process a by-product fraction of hydrocarbons containing five carbon atoms to the molecule is obtained. Isoprene is present in this fraction. By a series of fractionation steps, the isoprene is separated from the other hydrocarbons and concentrated to the desired purity.



STYRENE DISTILLATION COLUMNS, DOW CHEMICAL COMPANY, LOS ANGELES

The actual polymerization reaction is carried out by treating the mixture of isobutylene and isoprene with a catalyst at a low temperature. This results in a slurry of

small rubber particles in the reaction mixture. The resulting slurry is heated to flash off the unreacted constituents, which are reused, and the rubber particles are treated with hot water to destroy the catalyst. After screening to separate the water, the rubber particles are dried and then handled similarly to GR-S, or natural rubber.

Production of GR-M (Neoprene)

The government program contemplates an eventual production of 40,000 long tons per year of GR-M (Neoprene GN). For this purpose a plant located at Louisville, Kentucky, is being constructed and operated for the Government by E. I. du Pont de Nemours and Company, Inc. The du Pont Company also has a privately owned neoprene plant with an annual capacity of approximately 9,000 tons. The entire Government plant is now in operation at rated capacity. GR-M is produced by the polymerization of chloroprene to give a long-chain rubber-like material.

Preparation of Chloroprene. Chloroprene is a substituted diolefin containing four carbon atoms to the molecule, the same as butadiene, in which one of the hydrogen atoms has been replaced by a chlorine atom. Coal and limestone are heated electrically to produce calcium carbide which is used to prepare the light hydrocarbon gas, acetylene. The acteylene is polymerized to give monovinyl acetylene which is then reacted with hydrochloric acid to give the desired chloroprene. Chloroprene is a light substituted hydrocarbon that easily polymerizes with itself to give high molecular weight rubber-like materials. Since it is diolefinic in character, the resulting molecule has a high degree of unsaturation.

The actual polymerization of chloroprene to GR-M is carried out in a manner closely analogous to that employed for the production of GR-S. Chloroprene is emulsified with water, and the polymerization reaction is carried out with the aid of a catalyst. This results in a latex containing small particles of GR-M, which can be used as such for dipping and coating or can be coagulated to give a massed form of the polymer. The vulcanization of GR-M is effected by heat without the aid of sulfur as a curing agent.

Production of Buna-N

Buna-N is a synthetic rubber produced in a manner very similar to the production of GR-S, with the exception that the reaction mixture contains butadiene and acrylonitrile instead of butadiene and styrene. It is not being produced in Government financed plants or as a Government sponsored operation. However, priorities on equipment for the preparation of the polymer and its raw materials have been expedited by the Government rubber agencies.

Acrylonitrile can be prepared in several ways, but it is chiefly made from ethylene oxide and hydrocyanic acid.

As already stated, the actual process for the production of Buna-N is almost identical with that used for GR-S and it is handled in much the same manner. An annual production of approximately 24,000 long tons of Buna-N type rubbers is contemplated.

III

Comparison of Properties of the Various Synthetic Rubbers

GR-S is a general purpose type of synthetic rubber that processes and vulcanizes in a manner similar to natural rubber. In general, it has desirable physical properties, although in a few important characteristics it is definitely inferior to natural rubber for some uses. In other uses it is the equal, if not the superior, of natural rubber. It should be possible to use GR-S for most of the important uses of natural rubber. For example, it is believed that it will be possible to produce automobile tires that are about as satisfactory as the tires made from natural rubber. An intensive research and development program being carried on by a number of the rubber, petroleum, and chemical companies, and by educational institutions in cooperation with the Government, is continually developing improvements in the GR-S type of rubber. In fact, recent developments give promise of overcoming the most serious drawbacks of GR-S. In general, its processing characteristics are very similar to those of natural rubber. It appears very likely that within a few years this general type of rubber will be essentially the equivalent of natural rubber for most uses.

GR-I, owing to its different chemical char-

meter, has properties somewhat different from those of natural rubber and GR-S. While it may develop into a general purpose rubber, the main immediate uses will be those based on its special properties, such as its impermeability to gases and vapors, and its excellent age resistance. Thus, GR-I inner tubes hold air better than those made of natural rubber. It likewise should be useful for coating fabrics where impermeability to gases is important.

GR-M is a synthetic rubber that was employed on an appreciable scale prior to the present emergency, since it possesses special solvent resistant properties that are not obtainable with natural rubber. While the cost of neoprene was several times that of natural rubber, these special properties made it economically competitive. Neoprene also has excellent aging properties, particularly resistance to sunlight, and it is, therefore, valuable in covering fabrics that will be exposed, such as balloon fabrics. The GR-M produced in Government plants will be used largely for purposes for which its special properties make it valuable, although the quantity contemplated may be large enough to make some available for general purposes. It is satisfactory for general uses with the exception that it becomes brittle at the low temperatures that are likely to be encountered in high latitudes. The low temperature properties can be improved by the preparation of special copolymers of chloroprene, but the production of these copolymers is not now contemplated in Government owned plants.

Buna-N, which was produced on an appreciable scale before the present emergency, is also employed as a special purpose rubber. It has exceptional solvent resistant properties, particularly for liquids such as aromatic hydrocarbons. Essentially all the Buna-N is now employed in uses that are based on its solvent resistance. It could be used as a general purpose rubber, but its properties are not enough different from those of GR-S to justify its much more difficult processing and its much higher cost.

At the present time synthetic rubbers of the four types that have been discussed are being produced at an annual rate in excess of 500,000 long tons. Over the period of the next few months this production rate will be stepped up to the order of 600,000 to 700,000 long tons per year, and then sufficient synthetic rubber should be available for all essential uses.

The future of synthetic rubber is a question that is always raised when rubber production is under discussion. The problem is very involved and obviously will not be completely answered on purely technical and economical grounds. It is also undetermined whether the plants will continue under government ægis after the emergency or will be turned over to private ownership.

There is no question that special rubbers of the type of Buna-N and GR-M will be produced on an appreciable scale regardless of the cost or availability of natural rubber, because they are desirable for a number of uses for which the natural material is not satisfactory.

The case for GR-S and GR-I is not as clear as that for Buna-N because they will be more nearly in direct competition with natural rubber. It is believed that they can be produced for a price of fifteen to twenty cents per pound, including a reasonable amortization and return on the investment, and there is a possibility that they can be developed at a cost less than fifteen cents per pound. This price range compares favorably with the average price of natural rubbers over the past decade, but if the prevailing economic conditions in the rubber producing countries should be the same after the war as they were prior to it, there is no question that natural rubber can be delivered to the United States at a cost less than fifteen cents per pound and still show a satisfactory return for the plantations.

It appears likely that both natural and synthetic rubber will be used in the future. The availability of the synthetic rubber will stabilize the price structure and prevent the large fluctuations in prices of rubber that have prevailed in the past. It will also be very much to the national interest to maintain a synthetic rubber production large enough to meet the initial impacts of future emergencies. The continued use of synthetics over a period of years will also develop the necessary technical knowledge relative to their production and uses and will, therefore, obviate the intense research, development, manufacture, and testing that are necessary at the present time.

THE AMAZON—HAS IT BEEN FULLY DISCOVERED?

By ALBERT F. KUNZE

In the year 1502, more than a century before the Pilgrims landed on Plymouth Rock, while Henry VII, first son of The House of Tudor, ruled over Britain, the existence of the great Amazon was discovered. That was more than four centuries ago.

Today the potentialities of the Amazon River and its incomparable basin of some 2,722,000 square miles—over twice the estimated drainage area of the Mississippi and its combined tributaries—is still a vast region of undiscovered treasure. As the years progress chemistry will find uses for the myriad of plant species indigenous to the Amazonian basin; engineers will harness the untold horsepowers of energy that have, for centuries, wasted themselves in their journeys through the virgin jungles to the sea; botanists, biologists, and ornithologists will enrich their sciences with discoveries in regard to the flora and the fauna of the Amazonian tropics; and among other phenomena to be studied archeologists may analyze the earthly lamina of this "great unknown" to solve mysteries predating those of the Pre-Columbian era. In the fields of science the Amazon River is still a vast virgin world in itself, awaiting exploration and exploitation in the light of modern advancements.

Its long arms of flowing waters, capable of moving ocean craft for more than 2,000 miles westward from the Atlantic Ocean, beckon to the engineers of navigation, inviting them to utilize its watery pathway to bring to manufacturing and commercial centers, natural wealth that is so profusely to be found in but few places on the face of the earth.

The "dreamers" of the lands through which these waters flow have perhaps not failed to appreciate the potentialities of the natural assets that lie there unused. Three governments have, through the same medium, seen fit to invite attention to this watery Colossus of the Western Hemisphere. Their chosen vehicle of publicity has been drama in a picture form with which all

FIG. 1. (A) FRANCISCO DE ORELLANA (B) FRANCISCO PIZARRO

FIG. 2. (A) OLD MAP OF SOUTH AMERICA (B) ORELLANA AND HIS CREW

residents of their great areas are in intimate contact—postage stamps. Used by all who read, they convey their silent messages to the far corners of the world.

While it is true that none of the group of twenty-one stamps dedicated to the Amazon openly touches on the future development of this river, it is not at all improbable that this subject may have been in the minds of those who promoted their issuance.

In this era of experimentation many novel ideas have been tried. The direction and guidance of public thought is one development of political science that has received much attention. In the stimulation of national ideologies, postage stamps have played an important and surprisingly large part. World's Fairs, religious observances, and national industrial opportunities have frequently been depicted on postage stamps. On innumerable occasions political philosophies have been epitomized in the portraits of such heroes as Bolivar, San Martín, Washington, Artigas, and Sucre.

During the years 1940, 1941, and 1942 Ecuador, Peru, and Brazil dramatically invited attention to the mighty Amazon through postage stamps. In all three cases the four hundredth anniversary of the discoveries of Gonzalo Pizarro and Francisco de Orellana have been used as justification for these postal issues. Their adventures constitute a series of the most dramatic incidents in all of the sensational history of the unfolding of the Western world (Figs. 2A, 3).

In 1540 a substantial Spanish population had already gathered in widely separated localities of South America. The settlers, largely conquistadores and adventurers, had a fair conception of the general geographical characteristics of the land to which the lure of wealth had drawn them. Their ancient maps, as shown on the 40c. black and yellow air mail stamp of Ecuador, illustrate their fairly accurate concept of the vast South American continent.

Prior to that time, in the year 1500, Vincente Pinzon, one of the Captains of the original Columbus expedition, skirted the eastern shore of this great "island," as he presumed it to be. At a point close to the equator he fell upon a mystery more baffling than any he had previously encountered. The salty nature of the ocean had changed to fresh water. The aimless tossings of its billows assumed a slight current, directed toward no particular destination but emanating endlessly from between two points of land so widely separated that to his mind they could not have been the opposite shores of a river. As Pinzon sailed his ship westward between them he became more perplexed than ever, for nowhere in the experiences of Columbus, The Great Navigator, or the scientific discourses of Toscanelli, or the fantastic writings of Marco Polo, had the story ever been told of a body of fresh water

lying within or adjoining the great salty ocean. After sailing westward for several days against the increasing current, he christened the strange waters with the name "Mar Dulce" and contented himself with having it noted in his log, leaving the significance of the strange experience to others.

So incomprehensible was the enigma Pinzon had presented that the "wise men" of the old world demonstrated their wisdom by remaining silent. As a result four decades and longer passed before the world realized that Vincente Pinzon had, in fact, achieved one of the greatest discoveries of the New World. Pinzon and a whole generation of his fellow men died without ever having realized that he had discovered the giant of New World waterways, later named the Amazon.

To this day, and perhaps for all future time, however, the discovery of the Amazon will continue to be accredited to another conquistador. This capricious award of fame is no doubt attributable to the more sensational and melodramatic story of Francisco de Orellana and the manner in which he became associated with the Amazon. In truth, it might be recorded that, while Vincente Pinzon discovered the existence of the river, it remained for Orellana to discover its greatness and, vaguely, its course. Strangely, they approached the river from opposite ends, Pinzon unknowingly having entered its mouth and Orellana having traced its course down the eastern slope of the Andes, beginning 3,000 miles from its mouth in the highlands of the Republic now known as Ecuador.

CORREOS DEL ECUADOR
IV CENTENARIO DEL DESCUBRIMIENTO DEL AMAZONAS 1541-1941
SERVICIO AEREO
SERVICIO AEREO
OCEANO PACIFICO
OCEANO ATLANTICO
DEL PACIFICO AL ATLANTICO, ORELLANA DESCUBRIÓ LA RUTA FLUVIAL MÁS GRANDE DEL MUNDO. 1541-1542.
40 CUARENTA CENTAVOS
AMERICAN BANK NOTE COMPANY

FIG. 3. ANCIENT MAP
SHOWS EXAGGERATED IDEA OF THE AMAZON'S BREADTH.

The early seat of Spanish authority and military power centered about the Viceroyalty of Peru where Francisco Pizarro, the Viceroy, ruled with uncompromising authority. His fame and success was to a small extent due to the loyal prowess of his brother Gonzalo, and to his lieutenants Francisco de Orellana and Diego de Almagro (Fig. 4A). As the dominant Pizarro's prestige rose, so Almagro's ambition for recognition and reward increased, and as has so often been the case where friends of unusual prowess vie, disagreement soon arose. The Viceroy Pizarro knew but one satisfactory course to pursue when his power was challenged.

In 1538 he dispatched a substantial force of his military strength under command of his brothers Gonzalo and Hernando against Almagro, and assigned an important military task to his trusted friend, Francisco de Orellana. Their forces were large and their equipment surpassed that of Almagro who suffered defeat, and, after surrendering, the penalty of death for his insubordinate challenge to the authority of the Viceroy Francisco Pizarro. Gonzalo Pizarro was rewarded for his successes by being named Governor of the Province of Quito (Fig. 5B).

The military skill and the daring of Orellana in warfare so pleased the Pizarro brothers that the intrepid soldier received high praise and was rewarded with the title of Governor's Lieutenant General of the newly founded city of Santiago de Guayaquil, situated high among the peaks of the Andes. There he demonstrated that he was as proficient in civic administration as he had been successful in battle. Guayaquil, as a vassal city to that of the Viceroy, prospered and grew (Fig. 5A).

The early Spanish conquistadores, however, were not an agricultural people content

FIG. 4. (A) PIZARRO AND ORELLANA (B) ORELLANA, DISCOVERER OF AMAZON

to establish a community and live on such products of the land as its resources might offer. Gonzalo Pizarro well recognized that fact and found little difficulty in convincing his brother, the Viceroy, that it would be well to organize a strong force to move eastward to discover and take possession of the fabulous wealth of El Dorado, the Man of Gold, and of La Canella, the Land of Cinnamon. No difficulty was encountered in recruiting a following to proceed on an adventure that promised such rich reward. According to Indian report and tradition, El Dorado possessed wealth in gold that knew no bounds. The most menial utilities were made of the precious metal that glittered and scintillated in the brillance of the ever present tropical sun. It came from sources that were seemingly inexhaustible. El Dorado alone knew of their locations. Then too, in the same general direction as the abode of El Dorado, was the Land of La Canella where the fragrance of cinnamon perfumed the air with a deep, piquant, stimulating odor that surpassed the exotic and aromatic incenses of Oriental spice lands.

Toward the attainment of these rewards awaiting mere taking by the Spaniards, the adventurers rallied to the call of Gonzalo Pizarro. Several thousands, including Indian servants, made ready to follow the leaders appointed by the Governor, chief among them being Francisco de Orellana and Gonzalo Diaz de Pineda. With munitions of warfare, building materials, food supplies in casks and bales, and even livestock on the hoof, they finally got under way. Late in February of 1541 the advance unit of the expedition set forth (Fig. 6).

By day they traveled down paths of verdant grasses and at eventide paused in a cool ravine to enjoy relaxation and a satisfying meal. They gathered before open fires to revel in the interpreted stories of their native Indian guides. Each evening the Spanish adventurers relaxed to absorb further and more exaggerated stories of the glittering golden horde of El Dorado. As succeeding nightly camp fires were lighted, the men were assured that the land of their desire was but a few days further travel toward the rising sun. Each morning they arose at dawn fired with the certainty that the forthcoming day's journey would bring them closer to El Dorado. In their enthusiasm less consideration was given to the fact that

FIG. 5. (A) SANTIAGO DE GUAYAQUIL (B) QUITO, CAPITAL OF PIZARRO'S PROVINCE

food supplies were diminishing than to the hope of reaching their desired destination of gold. They appeared wholly oblivious to the fact that the dense vegetation through which they were forging their way offered no fresh supplies of food and that animal life consisted largely of snakes, lizards and ugly monsters that crawled on their bellies.

One day, however, the situation in regard to their lack of food stores dawned on them with startling emphasis. They held a consultation and it was decided that a brigantine was to be built which, freighted with their heavier burdens of munitions and cannon, was to move down the river to a point where, it was told, supplies of fresh meats and vegetables were to be found. There the heavier articles of their equipage were to be left, along with some of the men. Food was to be brought back on the return trip and then all were to proceed onward again to the Golden Land of El Dorado.

The plan was excellent. While the brigantine was being constructed of rough hewn forest logs, further consultations were held as to which of the Governor's lieutenants was to captain the ship. Gonzalo Diaz de Pineda was the only one seriously considered beside Francisco de Orellana. A decision was quickly reached, the former being assigned to remain with Gonzalo Pizarro and the main contingent of the soldiers, while Orellana accepted the honor and the responsibility of leading the contingent about to go forward for food.

In ambitiously accepting that assignment Orellana unknowingly was facing the turning point of his life. As a result of this new phase of his adventure, the high regard of the Pizarros, both Viceroy and Governor, was to turn from admiration to vindictive hatred, and the former praise he had received as soldier and as chief of the City of Santiago de Guayaquil was to be succeeded with charges of insubordination, treason, and treachery. As a matter of actuality his reputation became sullied with the most unkind and uncomplimentary aspersions which endured for centuries after he had died.

Orellana, born in 1511 in the town of Trujillo, Province of Esremadur in Spain, was the son of a prominent family. He was hardly more than a boy when he went to sea. In the service of Francisco Pizarro, to whom he was distantly related, he found a place among the early conquistadores who introduced the blood of Spain into the New World. During early life, in one of many hand-to-hand battles he lost one of his eyes, which added color to the infamous title, "the One-Eyed Traitor," by which he was long known in the records of history—accepted as authentic until the end of the nineteenth century.

In 1894 Jose T. Medina, a deep student of the source materials of writings long accepted as authoritative, completed a research that had engaged his major attention for a long period of years. He had taken issue with the record "created" by Jiménez de la Espada some three hundred years before, while lingering reflections of the old Pizarro-Orellana feud still persisted. Medina's views now appear not only to warrant favor, but to possess a logical sequence of factual data that

justifies the honor and prestige restored and rightfully belonging to Francisco de Orellana (Fig. 4B).

On December 26, 1541, amid salvos of good wishes and the cheers of his comrades, Orellana captained the brigantine his fellow adventurers had built and started eastward on what was to have been a mission of mercy in finding food and returning it to his companions. He planned to move downstream with the aid of his sails and the mild current, and then to return. The stream broadened as he proceeded, the waters took on a more powerful movement, and the jungle land became more dense, but neither villages nor edible vegetation greeted the ever watchful eyes of Orellana and his men.

From time to time occasional small bands of jungle natives greeted him through unfamiliar signs and incomprehensible mouthings. Through them Orellana was led to believe, or chose so to interpret their messages, that supplies of food were to be found ahead after another day of travel. But as each day waxed from noon to night, the quest lured him further down stream. The current increased, the river widened, and the waters,

CORREOS DEL ECUADOR
IV CENTENARIO DEL DESCUBRIMIENTO DEL AMAZONAS 1541-1941
SERVICIO AEREO
SERVICIO AEREO
LOS EXPEDICIONARIOS PARTIERON DE QUITO Y GUAYAQUIL ATRAVESARON LOS ANDES ECUATORIANOS Y DESCUBRIERON EL AMAZONAS
5 CINCO SUCRES 5
AMERICAN BANK NOTE COMPANY

FIG. 6. ALLEGORY OF EXPEDITION
WHICH ENDED IN THE DISCOVERY OF THE AMAZON

CORREOS DEL ECUADOR
IV CENTENARIO DEL DESCUBRIMIENTO DEL AMAZONAS 1541-1941
SERVICIO AEREO
DOS 2 SUCRES
RIO AMAZONAS CUYOS PRINCIPALES AFLUENTES NACEN DE LOS ANDES ECUATORIANOS.
AMERICAN BANK NOTE COMPANY

FIG. 7. THE AMAZON RIVER
ANCIENT MAP OF THE RIVER AND ITS AFFLUENTS

fraught with cataracts and rapids, rendered progress more dangerous with every hour. Each day his surroundings changed—even the character of the natives differed. In place of friendly Indians he met with a savage tribe whose greetings were conveyed by arrows with hardened tips bathed in the poisons of the jungle. They were an odd lot; according to the record of the historian Carvajal, they had fair skins, long blonde hair, and wore tunics that reached to their knees. As a result of this record, however clothed with imagination it may have been, these unfriendly natives were referred to as the feminine Amazon warriors of the New World. Battle with them and even flight from their missiles called for all the skill Orellana could command (Fig. 2B).

Orellana's food stocks ebbed and then disappeared entirely. The captain of the mission of mercy in search of food for his companions upstream began to realize that his temporary assignment had, for the time being, assumed less importance than his own growing predicament of danger. The increasing river current, the savage natives, and his crew of men whose morale had

reached its lowest ebb with cases of scurvy and other diseases prevalent, constituted problems that had changed the whole world for Orellana. In heart and mind he had not forgotten Gonzalo Pizarro and the mission he had been called on to perform, but as a practical matter there was no course for him to pursue other than onward into the indefinite spaces ahead at the mercy of the current and the winds. Had it been possible for Orellana to return to Pizarro, it was obvious that there was no point in taking that chance for the single purpose of reporting a failure to accomplish his objective.

Onward with the current Orellana willingly or otherwise plunged, finding the task of keeping the keel of his ship beneath him as much as he could manage. Torrential rains further handicapped his better management of the brigantine, the rains beating upon its deck with such force that the forecastle was not visible from the stern of the ship. Days followed weeks with a monotony varied only in the type and character of changing dangers. Time had lost its significance, direction had no meaning, even a destination was of less interest to Orellana than the ever present consequences of hunger. Starvation, scurvy, and death all took their toll as the nameless brigantine tossed and lurched its way down stream to an unknown destination.

St. Louis Day late in August of 1542 dawned and unexpectedly proved to be the end of a voyage auspiciously begun eighteen months before—a voyage that was intended to have lasted but two weeks. Orellana and his men had reached the Great Ocean, having traveled some three thousand miles eastward from the Andes. The original objective of their mission had long since been forgotten yet it was, according to Medina, "in this way that they brought to an end their navigation and experience which had been entered upon unintentionally and turned out to be so extraordinary that it is one of the greatest things that ever happened to men."

Orellana's original objectives of finding El Dorado and La Canella were never realized. His secondary mission of obtaining food for his companions was likewise never accomplished. For this latter failure he was censured throughout the realm of the Pizarros as having been a traitor in deserting his companions in the hour of their greatest need. In Spain, after the full extent of Orellana's journeys became known, he was acclaimed a hero on whom great honors were bestowed. But his triumph was transitory. At the height of his fame he was sent to Colombia to investigate a difficulty which had arisen between certain of the Spanish officials stationed there. After familiarizing himself with the situation he made the unfortunate error of ordering the arrest and imprisonment of several members of the "Audencia." The Council of the Indies in Spain, on reviewing the situation, disapproved of Orellana's action, and in turn, ordered him to prison where he died a short time later. So destitute was the great voyager, that it became necessary for someone else to meet the expenses of his funeral.

Despite the misfortunes of his own life, Orellana is today credited with the distinction of having been the first man to have navigated the entire length of the Amazon, thus bringing recognition of its immensity to the world (Fig. 7). His reports stimulated a series of exploratory voyages to and up the river and its several tributaries. Among them the most dramatic were those of Lope de Aguirre and, later, that of Pedro de Teixeira. Despite these explorations, the Spaniards acquired only a vague idea of the magnitude of the Amazon, its tributaries and drainage basin. This is evidenced by their crude maps, now obsolete, several of which are to be seen on the recent postage stamps of Ecuador and Peru. A fuller picture of the vast reaches of the Amazon, at least insofar as the Brazilian basin is concerned, is to be noted on a 1943 brown map stamp of Brazil released by Brazil in 1943.

The increased needs of world markets for many basic materials and substitutes for others, so sternly realized in connection with the prosecution of World War II, has brought a distinct change to the Amazon Basin. The great rubber industry has reawakened, embracing not alone the agricultural phases of cultivation but likewise the subject of manpower coupled with the endless human needs of food, shelter, and clothing for the workers and their families.

schools for their children, health and sanitation facilities, and the equally great problem of transportation by land, sea, and air. Rubber is said to have been indigenous to the Amazon valley, although later cultivated in the East Indies and Africa where it gained great commercial prosperity. From present indications it would appear that the Era of Rubber in the Amazon Valley is about to begin.

Quinine, a product of the bark of various species of the cinchona tree, is likewise a native of the Ecuadorean and Peruvian basins of the Amazon. The unprecedented movement of men to tropical climates in connection with the pursuit of World War II, so stimulated the need for the medicinal powers of quinine that the cultivation and treatment of cinchona trees of the Amazon valley have received an impulse greater than ever before. Woods of a wide variety, fibers, tin, manganese, and other natural resources in quantities and grades still unknown lie dormant in the huge Amazon Basin covering an area larger than that portion of the United States east of the Mississippi River. Many species of native flora of the Amazonian regions still remain subjects of chemical and commercial experimentation and exploitation such as the vegetable ivory trees, the babassú nuts and the carnauba palm. This latter species, which flourishes in the dry regions of the northeast has already received considerable attention. In regard to it Professor Fred A. Carlson of the Ohio State University has written in his *Geography of Latin America:*

> The root is depurative and is widely used in treatment of blood diseases. From the bark is prepared a meal which is highly prized. The trunk furnishes a wood employed in rough timbering. The fruit is an excellent food for animals, and when ripe, has a soft, dark, lustrous sweet pulp which is delicious either raw or made into a conserve. Around the fruit is a shell five inches in diameter, which when roasted, is made into a drink resembling coffee, and which yields an illuminating oil. From the surface of the young leaves comes the famous carnauba wax which is widely used in phonograph disks, in cinema films, in insulation for cables and in candles.

To science the great Amazon River and its far-reaching Basin still remain to be discovered with a view to a fuller use of their abundant natural wealth. As Vicente Pinzon in 1500 discovered the existence of the river, and Orellana in 1542 its length and course, so, even today, after a span of more than four centuries, there remains for discovery through the advanced sciences of our generation, a multitude of practical uses for the natural assets of the Amazon Basin.

Vatican
MYTHOLOGICAL AMAZON
FIFTH CENTURY, B.C.

AGAR: A VALUABLE SEAWEED PRODUCT

By C. K. TSENG

THE importance of agar[1] in culture media for bacteriological and other microbiological research is well known in the scientific world. The United States, like other countries, used to depend principally on Japan for her agar supplies. Under the present conditions this source of agar is no longer available. The resulting agar shortage has become the concern of the Government. Consequently much attention has been given to problems regarding agar by various scientists—bacteriologists, botanists and chemists. There are already several articles recently published in *Science* and elsewhere, on methods for reclaiming used agar, on new sources of agar, and on the preparation of agar substitutes.

AGAR: HISTORY AND NOMENCLATURE

In undertaking certain research problems with regard to the agar resources on the Pacific coast, the writer found a great deal of confusion existing in the use of the term agar. There is also misinformation about the sources of agar. The confusion is mostly due to the fact that the word "agar" or "agar-agar" was originally the Malay name for certain East Indian red algae, but is now almost exclusively used in science to designate the dried gelatinous extract derived from other seaweeds and produced principally in Japan. Thus, contemporary scientists writing on agar as we understand it nowadays not infrequently quote facts concerning *agar* as the word was used originally. Therefore, in order to avoid further confusion in this matter, it is necessary to standardize the application of the word "agar," restricting its use only to the dried extract. For the sake of simplicity the word "agarphyte" is here suggested to apply to the seaweeds used in its manufacture, instead of the more elaborate combinations of words such as "agar-bearing seaweeds," "agar-producing seaweeds," and "agariferous seaweeds."

The Original Agar. The original Malay word, *agar* or *agar-agar*, applies to certain common edible red algae, especially *Eucheuma muricatum* f. *depauperata* (= *Eucheuma spinosum*) of the Dutch East Indies, but is used indiscriminately for other species of the same genus. *Eucheuma muricatum* has been exported as *agar-agar* from the Dutch Indies to China for more than a century. It is quite common on Chinese markets, known under the popular name *Chih-ts'ai*, meaning "Unicorn Vegetable." Quite erroneously, most authors have assigned the name "agar-agar" principally to *Gracilaria lichenoides*, which, to the knowledge of the writer, has never been used in China for making agar or in Ceylon where agar has never been made.

Introduction of Agar into Bacteriology. The introduction of agar into bacteriology has been discussed in detail by Hitchens and Leikinde. These authors credit the discovery of agar as a medium for bacteriological culture to a housewife, Frau Franny Eilshemius Hesse, who suggested to her husband, a bacteriologist, the use of agar-agar "which she had been using for years in her kitchen in the preparation of fruit and vegetable jellies." This discovery was communicated by Dr. Hesse to Robert Koch, "probably late in 1881." Because agar gel is relatively inert, is not liquefied by most bacteria, and remains in firm consistency at the incubation temperatures for the growth of various types of bacteria, it has helped greatly to advance the science of bacteriology.

It is, of course, impossible now to determine what was actually the "agar-agar" which Frau Hesse and eventually Koch used in this important discovery. Hitchens and Leikinde make this remark: "While yet in America she had received the recipe from her mother; her mother in turn had obtained the formula from some Dutch friends who

[1] "Agar" is preferred to "agar-agar" for the sake of simplicity. The word is pronounced in Malay with both *a*'s as in "arm." To follow the native Malayan tongue strictly the *r* should be pronounced like that in German. In this paper, whenever the word agar refers to the original Malay meaning, it is italicized.

DIVER DESCENDING WITH BASKET TO HARVEST AGARPHYTES*

had formerly lived in Java." From this note it may be reasonably inferred that the material used was the true East Indian *agar-agar*—the seaweed *Eucheuma muricatum*, rather than the dried extract from Japan.

The writer has as yet no definite information as to when the Japanese preparation was exported to Europe in quantities, and when it began to be called by the Malay term. From evidences in the writings of botanists and chemists in the 19th century, it seems that the Japanese product was already known by the European scientists in the 1860's, that it was then a very rare article—probably not something which the housewives could use in their kitchens—and that it still had no connection with the word agar, which was invariably used to designate certain East Indian algae, especially *Eucheuma spinosum*. As late as 1893 the Japanese government in the World's Columbian Exposition still called this *Gelidium* extract merely "dried seaweed jelly," instead of agar-agar as might be expected if it were already known by that name and exported as such in quantities to the Occidental countries.

Modern Use of the Word Agar. At the beginning of the present century the Japanese scientists, such as Yendo, had already called this peculiar Japanese product "agar-agar." Somehow, because of the persistence of the bacteriologists, the scientific world has generally accepted as agar, without further questioning into its origin, the dried gelatinous *Gelidium* extract in the form of powders, flakes, strips, or blocks from Japan, rather than the seaweed *Eucheuma* itself, the true *agar-agar*. Using the term as it is now generally accepted by scientific workers and dealers, we must give the seaweeds from which this peculiar extract is commercially prepared a separate name—"agarphyte" as proposed here—in order to avoid further confusion in the matter of terminology.

Definition of agar. It is to be noted that the definitions of agar that have appeared in various contemporary standard works are partly incorrect and as a rule too vague, because they apply not only to agar but also to other red seaweed extracts, such as carrageenin from Irish moss. Although our present knowledge of agar is still too incomplete to warrant a definition that would be acceptable to all scientists, it is advisable that

* All photographs courtesy U. S. Fish and Wildlife Service.

a revised definition be available. Such a definition should be broad enough to include products most scientists would agree to call agar, but precise enough to differentiate it from closely related but definitely different products, such as carrageenin mentioned above. Therefore, the writer ventures to offer the following definition for agar: The dried amorphous, gelatin-like, non-nitrogenous extract from *Gelidium* and other red algae, being the sulfuric acid ester of a linear galactan, insoluble in cold but soluble in hot water, a dilute neutral solution (1 to 2 percent) of which sets, upon cooling, to a firm gel solidifying at 35° to 50° C., and melting at 90° to 100° C.

Agar Production and Consumption

There has been a good deal of misinformation in the literature about the sources of agar. For instance, Tressler writes in 1923: "Most of the agar of commerce comes from Japan, China, Malaysia, Ceylon and neighboring coasts." At that time none of these countries except Japan, of course, produced any commercial agar. One botanist makes the following remark in a publication in 1917: "In the past agar-agar has been made principally in Germany from algae obtained from Japan." To the writer's knowledge Germany has never produced any agar so far, although she has made a purified agar from the Japanese product. Such misleading notes have been quoted again and again in current literature.

Japan is most probably the first country to produce agar in its present form. There are several theories as to when the present method of agar manufacture involving freezing and thawing was discovered, and according to Horiuchi, the following four years have been suggested: 1647, 1655, 1658 and 1688. Recently Chase reported, "The Chinese introduced it to Japan in A.D. 1662." In a recent communication she wrote the writer that her information was based on an old Japanese encyclopedia. The confirmation of any of these theories will be of some historical interest.

Japan is, and probably will always be, the leading agar producing country, in view of the vast quantity of agarphytes produced on her extensive coast, her well established agar industry, her low cost of production, and the appreciation of agar as food by her people. Agar is produced principally in the Osaka, Hyogo, Kyoto, Nagano, Yamanashi and Gifu prefectures where the climate is favorable for its manufacture by the old method. Some agar is also produced in Karafuto (Saghalien) where it is extracted from a different material by a different method. According to Horiuchi in 1936, there were 512 establishments with a total output of 679,918 kans or 5,622,921 lbs., worth 9,712,497 yen, or about $2,400,000. The total export that year was 3,921,638 lbs., worth 5,574,452 yen, or about $1,400,000.

Up to the outbreak of war in 1937, China had a small agar industry consisting of three factories located at Ningpo, Tsingtao and Chefoo. No published data were available as to their total annual output. On the basis of information obtained from two of the firms and of the amount of agarphytes produced in China, the writer estimates the Chinese annual production at about 75,000 lbs., which normally was worth about 200,000 yuan, or approximately $50,000.

The United States has been making agar for about 28 years. The annual production has been very irregular, varying from 1,802 lbs. (1934) to 44,895 lbs. (1930), and in one exceptional year (1925) was as much as 117,773 lbs. Until 1941, when the domestic production was about 52,000 lbs., only one factory was actively engaged in making agar. The war has greatly stimulated the growth of this industry and now there are five concerns devoted to agar production, all located in southern California. The expected annual output will total 200,000 to 250,000 lbs.

In recent years Russia has also paid much attention to the production of agar from local seaweeds. According to Kizevetter, Vladivostok and Archangel each produced 44,000 lbs. and Vladimir 33,000 lbs., making a total output of 121,000 lbs in 1936. Besides, Odessa in the Black Sea was reported to have produced 440,000 lbs. of "agaroid" in the same period. This substance is probably of the nature of a seaweed gum similar to carrageenin. If, however, it proves to be a true agar as defined above, the Russian production in 1936 would have far exceeded

that of the United States even at the present rate of production.

The agar industry in the Netherlands Indies is a recent one. There were reported to be two factories in 1938. The total output was not known. At present both Australia and New Zealand are very actively investigating their agar resources. Recently Wood reports that an Australian firm is producing its own requirements for meat canning and that others will be making "agar" soon. This "agar" is undoubtedly in the form of a gel which is directly used in canning without passing through the freezing-thawing-drying processes, as the same author remarks, "no dried agar has yet been produced." Information reaching the writer reveals that South Africa has a rich natural resource of *Gelidium* and other agarphytes, still untapped, and enough to develop a great agar industry. A firm at Capetown was reported to have produced some agar-gel which was used directly in making confectionery. Perhaps these countries are producing some true agar by now. In Baja California, Mexico, from which came the majority of the *Gelidium* used in the United States in 1942, a small factory with a capacity of a ton of dry *Gelidium* per month is already in operation, and a larger one is being built.

On the basis of these data and information the writer estimates the world production of agar at six million pounds per annum of which 90 to 95 percent is made in Japan.

Japan also leads the world in the consumption of agar. According to Horiuchi, out of the total production of 2,207,378 lbs. in 1902, 366,542 lbs., or 16.6 percent, were consumed in that country. In 1936, while the production increased 2.6 times to 5,622,921 lbs., the consumption increased even more significantly by 5.7 times to 2,112,736 lbs., constituting 37.6 percent of the total production and about 0.35 ounces per capita. Agar consumption in China used to be over a million pounds per annum up to the early part of this century. Of the total Japanese export of 1,767,528 lbs. in 1906, 1,284,633 lbs., or about 73 percent, went to China and Hong Kong. In recent years, because of the enormous increase of price of agar, because of some local production, and because of the strained relation between China and Japan,

HAULING IN A BASKETFUL OF *GELIDIUM* WEIGHING ABOUT 65 POUNDS

the Japanese agar export to China has declined drastically. In 1938 China, including Hong Kong, imported only 109,592 lbs. Normally China would consume at least six to eight hundred thousand pounds annually for food alone.

The United States imports of Japanese agar during the last few years before the outbreak of war fluctuated between 500,000 and 700,000 lbs. In 1941, besides making 52,000 lbs., she imported 565,059 lbs. from Japan and 32,413 lbs. from China. According to Kizevetter, Russian consumption is about 660,000 lbs. per annum. In 1938 Germany imported 596,239 lbs., France 442,225 lbs., England 294,329 lbs., Dutch East Indies 162,393 lbs., Australia 144,571 lbs. and Strait Settlements 58,520 lbs., all from Japan. These imports represented, presumably, also the amounts consumed by these countries. It is to be noted, however, that the Dutch East Indies and the Strait Settlements have long been using a large quantity of local seaweeds to prepare their own agar gel.

THE AUTHOR GOES UNDER

DIVING TO STUDY GROWTH RATE AND QUANTITATIVE PRODUCTION OF *Gelidium* ON CALIFORNIA COAST.

Uses of Agar in Medicine and Science

Agar originally was used in making jelly and certain food preparations in the Orient. Since 1882, when it was first introduced into bacteriology, its technical uses have increased enormously.

As Microbiological Culture Medium. This is the most important use of agar, so far as human welfare is concerned, although the quantity of agar actually employed in this way constitutes only a minor portion of the total. Undoubtedly agar has received more respect and honor in this service than in all the others put together. Its chief value as a culture medium lies in the firm consistency of its gel at incubation temperatures for the growth of bacteria and other micro-organisms, and in its inertness towards most bacteria. These were the two main reasons which motivated bacteriologists in the latter part of the last century to prefer agar to gelatin as a culture medium. Agar is also remarkable for melting at about 95° C. and solidifying at about 40° C. Because it remains liquid when cooled to 42° C., organisms may be thoroughly mixed with it at a temperature that does not injure them; on the other hand, once it gelifies, it will remain firm at about the same temperature, usually 37° C., at which the pathogenic forms are generally incubated. The reversibility of the agar gel enables the operator alternately to warm it into the sol state and cool it into the gel state. Its firm, rubbery surface is not easily ruptured when organisms are streaked across it by needle. Pure agar gel is nearly transparent and neutral in reaction. All these unique characteristics of agar make it unexcelled as a bacteriological medium. It is also widely used in the preparation of semi-solid media. Having a ten times greater jellifying power than gelatin, it is a much cheaper material to use. Nowadays, not only bacteriologists, but also other microbiologists, as well as scientists working on pure culture and life history of fungi, algae and even orchids, have to depend greatly on agar media.

As Laxative. The popular use of agar as a laxative is based on its ability to absorb and hold water, becoming at the same time a lubricant and a mild stimulant. For this purpose it may be taken in various ways—

PRINCIPAL AMERICAN AGARPHYTE
A FEMALE PLANT OF *Gelidium cartilagineum*.

"HAIR AGAR"
AN ASEXUAL PLANT OF *Gelidium nudifrons*.

with cream and sugar, or in special chocolate-coated preparations, or as a mineral-oil emulsion. *Merck Index* remarks that "unlike drug cathartics, it is not habit-forming, and does not lose its efficiency or require increasingly larger doses." According to Chase, quoting Caravaggi and Manfredi, agar also contains certain laxative and purgative principles which act uniquely on the intestine by exciting peristalsis without affecting the functions of the stomach or the duodenum.

In Dental Impression Mold. In dental work agar has proved to be the best material for making impression mold. Although materials made of algin are recently being used to take the place of agar, dentists mostly agree that, if the latter were available, they would go back to it. The value of agar gel lies in its having a long temperature lag between liquefying and hardening, which factor is very important in this kind of work. For this purpose generally a very concentrated agar gel is used to which a dye and a disinfectant are added. In using it a small portion of the preparation is heated to become a fluid, cooled down to about room temperature, placed in the tooth socket or in the oral cavity, cooled thoroughly, and upon solidification the wanted impression is obtained.

Other Medical Uses. Agar has long been used to stabilize an emulsion to carry vitamins and other items like acidophilus milk. It has also served in wound dressing on account of its inhibitory action on blood-clotting. Used in a preparation applied beneath the bandage, it helps to quicken the healing process. Glycerine suppositories have been made with agar as a vehicle. In obesity it is said to be useful. According to *Merck Index* it is also used in glycerine jelly for chapped hands and in prosthetic work in surgery.

Agar as Food

As Food in the Orient. Agar has been and is used as a food in a great variety of ways in China and Japan. It should be noted, however, that agar has little nutritive value. A "food" in an Oriental sense may not necessarily be nourishing. Only the principal foods, like rice, need have nutritive value. The complementary foods, such as agar, may be merely appetizing. Up to the

early part of this century China had been importing from Japan annually over a million pounds of this commodity entirely for food. It is frequently served as a substitute for the expensive birds' nests. For this purpose the best grade of agar, which will not dissolve too readily in the hot soups, has to be used. It is also used in a special kind of "cold dish"; the agar strips are cut into smaller pieces, washed by soaking in cold water, placed in hot water, taken out before they show any signs of going into solution, and then mixed up with some good grade of soya sauce, some black vinegar and sometimes a few other ingredients such as red pepper. In Japan, agar is also cooked with rice, and with seasoning it forms an "agar-rice." Sweetened and flavored agar-gel is a favorite "cool diet" in the summer in hot countries such as South China and Malaya.

As a Food Adjunct. In recent years agar has been used extensively as an adjunct in various food preparations. Generally speaking it serves as a substitute for gelatin where the latter, for one reason or another, is unsuitable; it has also proved to be very economical, since, on account of its high gel strength, a relatively small amount is needed. It is used in confectionery throughout the world wherever agar is known. The confectioner can make a healthful jelly candy with less sugar by using agar in about half to one percent solution. In the preparation of drinks, such as malted milk, it provides a healthful body and acts as a stabilizer. Added to bread and pastries it helps to keep them from drying out, on account of its moisture retaining ability.

In the manufacture of frozen dairy products, agar has been most successfully used in sherbets and water-ices. It makes them smooth and prevents the drainage of unfrozen sirup out of them in the hardening room. Unlike gelatin, it acts quickly, and aging of products containing agar as the stabilizer is unnecessary. It making ice cream it also imparts a smoother texture to the preparation. The use of agar has helped to make a firmer bodied cheese of improved slicing qualities. Desserts and salad jellies made with agar have the distinctive advantage of setting rapidly and certainly, even in very warm climates. Being unassimilable and having high water absorbing capacity,

AGARPHYTES GROWING ON ROCKS NEAR LA JOLLA COVE, CALIFORNIA
Gelidium cartilagineum FLOURISHES IN EXPOSED PLACES WHERE WATER IS TURBULENT AND FAST.

it is an excellent roughage, recently used extensively in many breakfast and "health" foods.

In Meat and Fish Canning. In terms of agar consumption per capita, Australia is second only to Japan, using about fifteen hundred thousand pounds, or about 0.25 ounces per person per annum. The major part of this agar is said to be employed in meat and fish canning. It helps to keep the softer types of meat and fish from falling apart. Its ability to retain its gelatinizing power in a greater extent than animal gelatin, after subjection to the high temperature necessary in processing these foods, makes it superb for this particular purpose. New Zealand normally uses thirteen tons per annum for canning sheep's tongues. It is the writer's conviction that the use of agar in meat and fish canning will become more and more popular in the years to come. At present it is not being utilized in this way in this country as much as it should be.

In Meat and Fish Preservation. Agar provides a rather simple but effective way of temporarily preserving easily spoiled foodstuffs like meat and fish. It is especially recommended for hot countries where refrigeration is not available. The meat to be preserved is cooked with some agar and the resulting meat-gel will remain wholesome for quite a long time. The agar is not attacked by most putrefying bacteria, and thus it helps to prevent the entrance of oxygen and bacteria which will otherwise spoil the meat.

Agar in Industries

In early days agar was extensively used in oriental industry in fabric sizing and in rendering rice paper more durable. It was also employed in making waterproof paper and cloth, which were used in China to wrap expensive porcelains and bronzes for exporting to Europe. In other countries such waterproof wrappings also served to prevent corrosion of munitions.

At present agar is still being used in the textile industry, but only in silk sizing and in the warp of silk. In the modern paper industry agar is utilized to some extent as a paper coating to impart resistance to the penetration of resin, wax and grease. It is used to make the gelatinous rolls in hectograph duplicators. In the tanning industry, it serves to impart a gloss and stiffness to leather in the finishing process. It is employed as an ingredient of calcimine and shoe stains. Occasionally it is also used in the making of molds required by workers in plaster of Paris.

Agar also renders its services to agriculture as a supplement in nicotine sprays for insect pest control. In the cosmetic industry agar is used as the base of certain non-grease preparations, shaving soaps and hand lotions. It is also employed as a binder in certain dentifrices. The least expected, but important, use of agar is in the electrical lamp industry. In the hot drawing of tungsten wire, a lubricant is necessary to facilitate the drawing operations and reduce the wear on the die. Westinghouse uses a lubricant made of homogeneous suspension of powdered graphite in agar gel. In Japan, agar is also employed in making electric lamp shades.

Among the recently discovered promising uses of agar is its application in making photographic plates and films. Actually, more than twenty years ago patents were already issued in Germany covering such use of agar. That agar was not extensively used for this purpose was due to the fact that certain chemicals present in gelatin, but not occurring in agar, were necessary in making the sensitive emulsion. Recently it was found that these substances could be successfully added to agar. With this problem solved, agar is said to be superior to gelatin for photographic films because an agar film need be only one eighth the thickness of a gelatin film, is less soluble in water, does not melt in the tropical heat, and is cheaper. One firm is said to assert that agar is a better substance for supporting sensitized emulsion than any similar material now on the market.

There are undoubtedly many more uses of agar of which the writer is not aware and the number of its uses is expected to increase. At present no published data are available as to the amounts of agar used annually for the above mentioned purposes. According to information from agar dealers and various other sources, the 650,000 lbs. of agar used annually in the United States before the war were distributed approximately as follows:

Laxative	100,000
Microbiological culture medium	100,000
Bakery	100,000
Confectionery	100,000
Dental impression mold	75,000
Meat packing	50,000
Emulsifier	50,000
Cosmetic	25,000
Miscellaneous	50,000

Kinds and Sources of Agarphytes

There is a good deal of misinformation regarding the different kinds of commercial agarphytes and their geographical sources. *Gracilaria lichenoides* (=*Sphaerococcus lichenoides*, *Plocaria candida*), which has undoubtedly been mentioned the most frequently by writers reporting on agarphytes, is actually a very unimportant and negligible source for commercial agar. Another commonly cited plant for making agar is *Gloiopeltis tenax* (=*Sphaerococcus tenax*, *Plocaria tenax*, *Gigartina tenax*, *Gracilaria tenax*). It has never been used for this purpose. The genus *Gigartina* has been credited with a share in agar manufacture; again, not a single species has ever been commercially utilized in this manner, so far. The "Gelidium corneum," supposed to be the principal agarphyte, is still a taxonomic mystery remaining to be solved; it should be removed from the list of agarphytes until its true identity is revealed. According to Kizevetter and others, *Phyllophora rubens* is used in making "agaroid," which may not be a true agar, and is therefore excluded at present.

The list of agarphytes is certainly a lengthy one. There are, however, only a few which can be said to be the principal sources of agar: *Gelidium Amansii*, *G. cartilagineum*, and *Ahnfeltia plicata*. Besides these there are about forty other red algae, most of which are used merely as supplementary materials to mix with the principal agarphyte in agar manufacture. The American factories use almost exclusively *Gelidium cartilagineum* (L.) Gaill. which forms the "agarweed" of the commercial divers.

AGAR-PRODUCING SEAWEED
Gracilaria confervoides FROM SAN DIEGO BAY.

ELECTRIC WAVES—LONG AND SHORT

By J. O. PERRINE

Of all the tools of war and peace now doing valiant service, there is none more potent and versatile than the electric wave. In the past the natural sound waves of human speech and the natural light and heat waves of the sun and, of course, the water waves of the seven seas were the principal waves which touched life. Prior to the nineteenth century artificially made electric and sound waves played a minor role in peace and war. Today waves of many kinds—long waves, short waves, and microwaves of sound, heat, light, and electricity—engage the efforts of scientific workers of university and industrial laboratories.

These waves make new environments for all people. The word "wave" itself has a place in the vocabulary of laymen as never before. Waves have become more and more a commonplace in peace times. In 1943 waves, particularly artificial electric waves, went to war.

Electric Waves of Many Lengths

For the needs of home and industry and on the war front, long electric waves carry large amounts of power for heat, light, and machines. The sixty cycles per second wave guided by the high tension lines of the power engineer is five million meters long. Expressed in English units, it is 5,468,000 yards long.

Likewise, for the needs of home and industry and for the conduct of the war, a great array of electric waves bearing small amounts of power are used in the communication systems in all parts of the world. Each day millions of messages are borne by both the guided and unguided waves of telegraph, telephone, and radio. In general the radio waves in these day-to-day practical fields range from five meters to thirty thousand meters in length, and up to one million meters for speech waves and telegraph waves on wires. Those waves sometimes referred to over the radio as short waves and used for transoceanic communication, range from about five meters to about twenty meters. Standard broadcasting uses waves from five hundred and fifty meters to sixteen hundred meters.

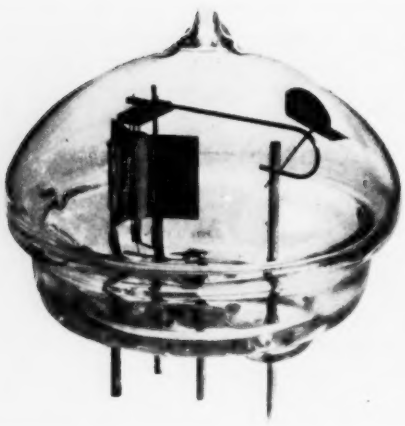
At the other end of the gamut of electric waves are the micro-microscopic waves of X-rays and those emitted by radium, called gamma rays, both of which may heal the wounds of man and give information concerning the nature of the physical world in which he lives. The shortest waves that have been found by the inquisitive mind of man are not the very short waves of X-rays and radium but rather those known as secondary cosmic rays. Contrasted to the sixty cycles per second (in some cases twenty-five) and the five million meter wave of the power engineer, the secondary cosmic rays have frequencies as high as one million million million cycles per second and wavelengths as near the nadir of nothingness as .000,000,000,000,3 millimeter.

Octaves of Waves

In the realm of vibrations, the octave is the well-established term used to indicate a frequency which is twice greater than some other frequency. The term is usually applied to the sound vibrations of music in which a note having twice the frequency of another is said to be an octave above it in pitch. On the piano there are about seven octaves, thirty-two to 4,096 vibrations per second; 32, 64, 128, 256 and so on to 4,096. Although the octave denotes a one hundred percent change in pitch, the higher note of a pair of semi-tones, anywhere within the octave of the musical scale, is six percent greater in frequency than the lower note. The human ear can hear frequencies from about sixteen to eighteen thousand, a range of ten octaves. Using this concept of octave to help appreciate the amazing breadth of the array of electric waves known to man, we find the gamut of electric waves, long and short, to be about eighty octaves.

A Family of Electric Waves

It was a great sally of imagination when



THIS VACUUM TUBE OSCILLATES AT 740 MILLION CYCLES PER SECOND WAVELENGTH 40 CM. 2½ INCHES IN DIAMETER.

man first regarded a wide variety of seemingly different kinds of waves as examples of one great category, the electromagnetic. Visible light, ultraviolet waves, infrared waves, heat waves, electric waves, X-rays, radium rays, and secondary cosmic rays are, after much study and reflection, regarded as waves of the same kind. Their distinguishing physical characteristics are wavelength and frequency of vibration. Their origins are different, their capabilities are different, their uses are different, but all are members of the same family.

An outstanding property of all the waves of the electromagnetic family is their amazing swiftness of flight. No other kind of waves, no projectile, vehicle, or moving thing in the entire universe travels so fast, namely, one hundred and eighty-six thousand miles (three hundred million meters) per second. The telephone, the telegraph, the radio, television, the radar, the X-ray, the camera—all do their tasks so marvelously because of the incredible speed of electric waves. A poet wrote many years ago about the telegraph:

> The electric nerve whose instantaneous thrill makes next door neighbors of the antipodes.

Infrared and Ultraviolet

The background and basis for our comprehensive concept of electromagnetic waves began about 1800. At that time, as for centuries before and centuries to come, the visible spectrum as seen in the rainbow was and ever will be a thing of sublime beauty. By the simple means of a triangular glass prism sunlight can be readily split into several colors. This artificial experiment provided an explanation and understanding of the natural rainbow. Newton made that great contribution in 1666. We now know that the colors of the rainbow extending from red light to violet cover only a single octave of vibrations, namely, three hundred and seventy-five million million to seven hundred and fifty million million. In wavelength, visible light varies from .0008 millimeter in the red to .0004 millimeter in the violet. It is surprising and stirring that this one octave makes possible so much beauty of tint and shade. One octave of sound would surely not be enough for a Beethoven or a McDowell.

In 1800, the elder Herschel repeated the experiment of Newton. But he did more than merely repeat an experiment. He obeyed an impulse to try something new. He held a thermometer in the streaks of color streaming out of the face of the prism upon a white cardboard to find out about the relative amounts of heat. He discovered the violet to be the coolest and the red to be hotter. But the drama does not stop there. He was happily surprised to find that his thermometer indicated still higher temperatures in a region outside the band of visible light and adjacent to the red rays. The invisible longer rays were called infrared rays. Here was a totally unexpected epoch-making discovery—not all of the spectrum of waves in sunlight was visible.

Soon afterward another invisible extension of the spectrum was discovered outside the angle of emergence of the violet light. It was called the ultraviolet. It is a surprising fact that only a small portion of the sun's radiation is in the visible spectrum; most of it is invisible. The infrared extends about seventeen octaves below and the ultraviolet about six octaves above the sides of the one octave of visible colors.

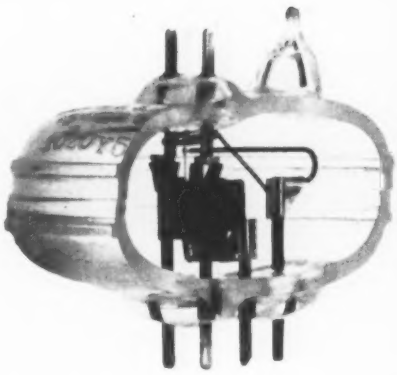
Light Waves Are Electromagnetic

No further additions were made to the radiation spectrum for half a century. It is likely, furthermore, that the existence of other waves was not even suspected. However, in 1866 there occurred a most significant episode in the saga of waves. Clerk

Maxwell, a Scoth mathematician and natural philosopher (now called a physicist) working at Cambridge University, England, made the first great sortie of speculation regarding visible light and its two neighbors, the infrared and the ultraviolet. He proposed that these three radiations, generally called light, were electromagnetic in character. Electricity and magnetism were then, and are now, fertile subjects for theory and experimentation. Magnets and electric charges had been found to have regions of disturbance about them, fields of influence extending into space. To Maxwell and his predecessor, Faraday, the fundamental reality was neither the physical piece of iron called a magnet nor the electrically charged metal sphere. The real crux of the phenomenon was the regions of space around the magnet, on the one hand, and around the charged sphere, on the other hand. There was a sort of radiation field of influence present in each case. The fields were quite distinctly different in character, one magnetic and the other electric, detectable by intrinsically different techniques. There was a suggestion of waves in these fields. With much observation, meditation, and mathematics, Maxwell suggested that electromagnetic waves might exist and, furthermore, that light waves were really electromagnetic in character. He made the scintillating prediction that electromagnetic waves, longer than the infrared, might be produced artificially and that they might be detected by distinctively electromagnetic means.

Discovery of Radio Waves

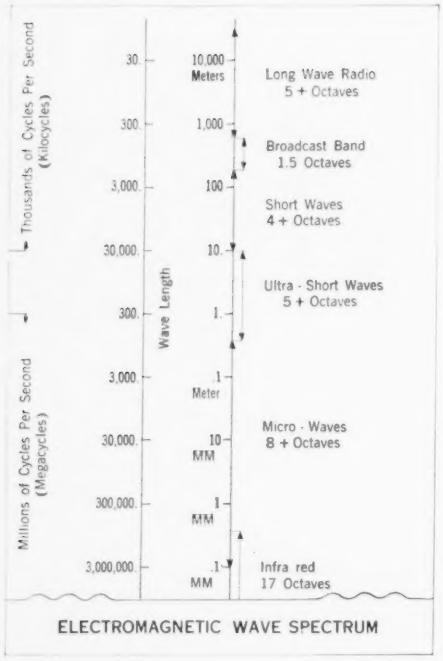
Twenty years later, in 1895, Heinrich Hertz, a German natural philosopher working at Karlsruhe with simple apparatus and electrical arrangements, produced and transmitted electric waves, and proved he had done so by receiving and detecting them with electrical apparatus. Hertz had brilliantly confirmed the startling prediction of Maxwell. Hertzian waves were sent through space fifty feet without wires. Their wavelength was fifteen feet corresponding to sixty million cycles per second. It was indeed an important milestone in scientific history, the peer of any political or military episode. It is interesting that the first electric waves ever produced were short waves, as we think of them today. Hertz later produced ultrashort waves of five hundred million cycles and twenty-four inches (600 millimeters) in length.



ELECTRON TUBE FOR THE PRODUCTION OF 2000 MILLION CYCLES A SECOND WAVELENGTH 15 CM. 2 INCHES IN DIAMETER.

Heat Waves Meet Electric Waves

Maxwell and Hertz, combining great analytical talent and experimental skill, had erected a great amphitheatre of knowledge out of which opened many doors. The electromagnetic spectrum became a fertile and challenging field of research. There were the natural means of short-wave production such as the sun, glowing embers, and the ordinary flame. By artificial means, long electric waves could be produced. The provocative question was, could all wave-lengths and frequencies be produced? Could waves be made by electrical means so short that they might even be called heat waves? Could heat waves be made so long that they might be called electric waves? It was a thrilling search for electromagnetic waves of intermediate length to bridge the gap between Hertzian waves and the longer infrared light waves. For several years the short electric wave record was held by Bose, of India, who produced and measured electric waves 75,000 million cycles per second and four millimeters long. The electrical vibration frontier moved forward slowly. To attain waves .22 millimeter in length required another twenty years of research.



During the same interval of about twenty years following Hertz, similar progress was being made in the discovery of long heat waves. At first progress was rapid. By 1900, far infrared frequencies of roughly three million million cycles and one-tenth millimeter in length had been attained.

In 1910, E. F. Nichols, then of Columbia University, made notable progress by producing and measuring long heat waves of four-tenth-millimeter. He used sensitive thermocouples (electrical thermometers as detectors). The same method, but with cruder instruments, had been used by the elder Herschel a century before.

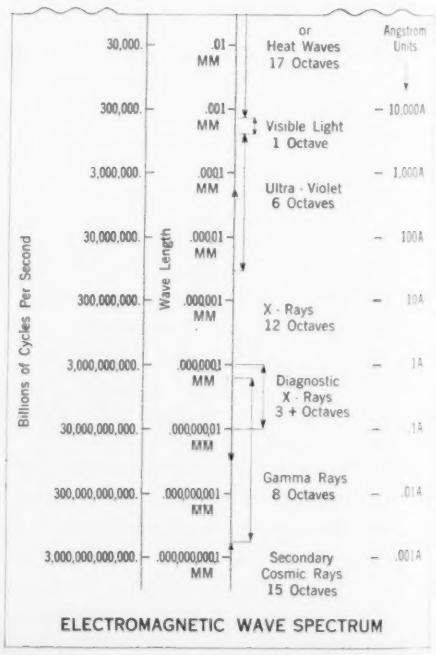
The gap between four millimeters and four-tenth millimeter does not seem to be a wide gap. It is over three octaves, however, over three times as wide as the entire visible spectrum. This unexplored gap resisted all efforts to bridge it for another decade.

The final bridging of the gap came in 1924. Again Professor Nichols and his co-worker, Dr. Tear, succeeded in extending both frontiers. Longer heat waves were produced and measured, and shorter electric waves were produced and measured. The gap was not only bridged but also overlapped about an octave. Electric waves of the amazingly small wavelength of .22 millimeter and heat waves .42 millimeter were produced. Shortly afterward Arkadiewa, in Russia, succeeded in producing electric waves .08 millimeter long. Through the years scientists had the will, the brains, and the skillful technique to fill out the spectrum between heat waves and electric waves. Their success was of great practical value as well as a notable scientific achievement.

Today Hertzian waves, radio waves, or electric waves, by whatever name one wishes to call them—one may always properly call them electromagnetic waves—are produced by laboratory means over a range of twenty-five octaves. In this broad span, many times the visible spectrum in length, these waves vary from about thirty kilometers (one kilometer equals .62 miles) to .1 millimeter (twenty-five millimeters equal one inch). Expressed in vibrations, this would be a range of ten thousand cycles per second to three million million cycles per second.

X-Rays

The thrilling achievement of the production of all electromagnetic waves of greater wavelength than red light is matched by the success in electromagnetic wave production in the region shorter than the violet light. As



has been stated, the ultraviolet region covers about six octaves of waves shorter than the violet. The longest ultraviolet wave is about .0004 millimeter and the shortest is about .000,003 millimeter.

In 1895 Roentgen discovered a "new kind of light," a hitherto unimagined and unpredicted kind of radiation. He was experimenting with the action of electricity in vacuum tubes. Much was known about the general behavior of electricity, how it served man, how it performed certain tasks, but not much was known about electricity itself. The passage of electricity through wires and liquids gave no clue as to its real nature. However, the visible effects disclosed when it was sent through various gases in vacuum tubes gave promise of finding out its intrinsic character. The situation was prophetically and elegantly described by Sir J. J. Thomson in 1893:

> The phenomena attending the electric discharge through gases are so beautiful and varied that they have attracted the attention of numerous observers. The attention given to these phenomena is not, however, due so much to the beauty of the experiments as to the widespread conviction that there is perhaps no other branch of physics which affords us so promising an opportunity of penetrating the secret of electricity; for while the passage of this agent through a metal or an electrolyte is invisible, that through a gas is accompanied by the most brilliantly luminous effects, which in many cases are so much influenced by changes in the conditions of the discharge as to give us many opportunities of testing any view we may take of the nature of electricity, of the electric discharge, and of the relation between electricity and matter.

In tune with the J. J. Thomson philosophy, Roentgen had been working with a Crookes tube, a form of vacuum tube containing gas at low pressure. Carefully covered photographic plates were found to be blackened when accidentally left lying near Roentgen's apparatus. Not knowing what the radiation was, he called them, probably as a result of his studying algebra in his school days, X-rays, unknown rays.

These X-rays penetrated and passed through wood, paper, flesh, and many materials opaque to visible light. It was natural to think of them as a "new kind of light." It was believed that they were electromagnetic waves, since Maxwell's suggestion that light waves were electromagnetic and his prediction, substantiated by Hertz's experiments, that longer waves could exist, had been generally accepted. If X-rays were a kind of light wave, then they should exhibit one of the simplest phenomena of light, namely reflection. All attempts to reflect X-rays failed and continued to fail for seventeen years. Then the brilliant flight of imagination of another physicist, Laue by name, gave a clue as to the reason for failure. He suggested X-rays were many-fold shorter than visible light. All the reflecting surfaces that had been used were literally too rough. For sound waves several feet long, a brick wall, layer upon layer of brick with mortar between, is relatively a smooth surface and so sound echoes result. For very short light waves, .0004 millimeter in length, the layers of brick and their intervening strips of mortar are too rough for regular reflection. One must have a highly polished surface. According to this principle, Laue said X-rays are so very short that even the most highly polished mirror attainable was still too rough.

In the intervening years atoms and molecules, the beautifully symmetrical crystals of rock salt, quartz, and other materials had been the subject of many researches. Laue therefore further suggested that the atoms in crystals might stand in rank and file like the bricks in a brick wall, however, with no mortar between them. Since they were so small themselves their rank and file, their façade, not the outside surface of the crystal but the façade of the atoms within the crystals, would be smooth enough and regular enough to reflect X-rays.

In 1912 the first experiments to test this conjecture were tried. From the very beginning they were a brilliant success. A great scientist's brilliant speculation had brought a great advance. X-rays falling on crystals were reflected. Furthermore, they were diffracted, that is, bent around super-sharp corners as are water waves around the end of a pier. For many years X-rays had been a sort of scientific waif, with an anomalous given name, "a pulse in the ether." In 1912 they were given a surname, Electromagnetic Wave. X-rays became a member of the family of light, heat, and radio waves. Their wavelengths had become measurable and, as predicted, were found to be shorter than those of ultraviolet light. The less pene-

trating ones known as soft X-rays are about .000,000,4 millimeter. Diagnostic and therapeutic X-rays, more penetrating, or "hard," range from .000,000,1 millimeter to .000,000,01 millimeter. As other gaps have been closed, so the gap between X-rays and ultraviolet light has been successfully bridged. In fact, the longest X-rays have not only met the shortest ultraviolet but have also substantially overlapped. X-radiation covers about ten octaves.

The cases of radio waves and X-rays present an interesting contrast. Radio waves were predicted twenty years before they were found to exist, 1866 (Maxwell)—1886 (Hertz). X-rays were experimentally produced seventeen years before their real identity and character were understood, 1895 (Roentgen)—1912 (Laue).

It is particularly interesting that although crystals were used to study X-rays at the start, in later days X-rays were used to study crystals. These researches have penetrated crystals and determined the groupings of the atoms of which they are composed, the distances between their atoms, and the directions they are located one from another.

Gamma Rays

Radio waves of useful character and X-rays are splendid examples of the ability of man to produce waves which are not made in nature's workshop. These two groups of waves of widely different wavelengths are entirely artificial. Imagination and constructive skill have produced important electromagnetic radiations that nature does not manufacture. One might argue that lightning flashes are accompanied by radio waves and that nature does, therefore, manufacture static radio waves. But at least useful radio waves and electricity as a tractable and serviceable agent are not part of nature's bounty. Useful X-rays, then, are strictly artificial; they are not produced anywhere in nature and are not the accompaniment of any natural phenomenon.

However, nature does manufacture electromagnetic waves similar to X-rays but considerably shorter. These waves are called *gamma rays*. They were discovered, interestingly enough, only one year later than X-rays. In 1896, Becquerel observed the phenomenon of radioactivity, a field in which Madame and Pierre Curie carried out brilliant researches and discovered and isolated the principal exhibitor of radioactivity, radium. In the process of radioactivity, there is a spontaneous breaking down of matter, an atomic volcanic action. Accompanying the disintegration of heavier atoms into simpler and lighter atoms, the gamma ray, a different "kind of light," is emitted. Since ordinary light accompanies the rapid vibration and scurrying about of atoms in incandescent lamp filaments and glowing metal and heated objects in general, it is not surprising that during an atomic explosion there should be some sort of electromagnetic radiation. The gamma rays are super-short and are readily detected and measured. Their wavelength is in the neighborhood of .000,000,003 millimeter and covers a range of about eight octaves. The X-ray spectrum and the gamma ray spectrum overlap in the region of the shorter X-rays. The therapeutic effect of radium involves the gamma rays, which are generally comparable in wavelength to the shortest of the therapeutic X-rays.

Secondary Cosmic Rays

Finally in the field of electric waves, long and short, are the secondary cosmic rays. Their spectrum extends far out from the shortest gamma rays for some twelve or fifteen octaves. As has been stated, the frequency of the shortest radio wave capable of being manufactured is three million million cycles per second and a fraction of a millimeter in wavelength. The frequency of the secondary cosmic ray may be as high as a million million million million cycles per second, which corresponds to an incredibly small wavelength.

Primary cosmic rays are apparently high-speed particles which come to our earth from the interstellar regions and perhaps from beyond the borders of our Milky Way system. When they strike our atmosphere, secondary cosmic rays are produced. These latter rays possess great energy and are capable of passing through several feet of lead. Radio waves, long and short, travel long distances through air and pass through many mate-

rials. Heat waves, light waves, ultraviolet waves, X-rays, gamma rays—all penetrate various substances. The secondary cosmic rays, micro-micro waves, are the most penetrating waves of all those yet discovered. They have been detected in the deepest mines and deepest lakes after having passed through hundreds of feet of rock and earth and water.

The Qualities of Electric Waves

Like the members of a human family, the members of the electromagnetic family exhibit widely varying qualities and capabilities. Different parts of the spectrum must be studied by different methods and with different apparatus. Different parts are useful for widely different purposes and some parts are not as yet used at all. The very long waves of the power engineer perform arduous tasks and do lots of work in home and industry. They are studied with meters to measure amperes, volts, and watts. Only one-fourth of the eighty octaves of the spectrum are used in communication to carry code messages on the one hand and facsimiles of speech and music on the other hand. Sizable meters of various kinds are used in this field, too. In the radio region electrical resonance, or tuning, is the technique of reception and detection. The measuring instruments are of the same type but not as large. As the shorter waves were mastered, a sudden and drastic change was necessary in the instrumentalities of study. In the far infrared, the thermometer, particularly the sensitive electrical thermometer, is the detecting device. In the near infrared, either a thermocouple or photography is used. Several methods are available for research in the visible spectrum, including human vision. But since the eye is unreliable for purposes of measurement, thermocouples and photoelectric cells, and most of all photographic plates, become necessary tools. For the ultraviolet and X-rays, photography is commonly used.

The ultraviolet has sun-tanning and blistering effects and certain wavelengths have germicidal effects, but for quantitative study nothing else is quite so satisfactory as photography. The ordinary photographic film is very sensitive to ultraviolet light; less sensitive to the blue-violet of the visible spectrum; and rather insensitive to the red.

Some living organisms are not only benefited but also dependent upon light for growth; others are killed by visible light and ultraviolet; some compounds will literally explode when light strikes them. The tissue of the human body is unaffected by radio broadcast waves but is warmed by infrared waves and is stimulated and even burned by light, ultraviolet waves, and X-rays.

In addition to the many so-called practical uses of the waves of the electromagnetic spectrum, a study of this spectrum has made possible an outstanding contribution toward a further basic understanding of the world in which we live. The ever engaging and challenging question has been, What is matter? Light waves, heat waves, infrared waves, X-rays, and all the other frequencies give clues as to the arrangement and motion of atoms and molecules and electrons. They are all tools which have supplied new and stimulating knowledge as to the intrinsic nature and architecture of matter.

The qualities of gamma rays and cosmic rays are most reliably studied by means of the ionization chamber. When these rays penetrate a gas enclosed in a tube, that gas is made a conductor of electricity; the device is called an ionization chamber and becomes the instrument for measurement.

X-rays and the gamma rays of that amazing element radium are both remedial and dangerous. They destroy good tissue as well as diseased tissue and germs of every kind. The goal of the physicist and the biologist is to find the technique of measurement and dosage that will take more and more advantage of the fact that these radiations destroy diseased tissue a little faster than healthy tissue.

All of the waves in the electromagnetic spectrum carry power. They are all forms of radiant energy. They are not of themselves color, they are not light, chemical action, heat, photoelectric effect, or sunburn. When waves bearing widely varying amounts of power and oscillating with widely varying frequency are received, the effect produced by them in the receiving material or receiving device may be heat, light, color, speech, music, chemical or physiological change.

The effect produced depends almost as much on the receiving device as it does on the frequency involved. Of course, one would hardly expect the ultraviolet rays of the sun to actuate a radio receiving set or radio waves to tan the human skin. However, with the provision of the appropriate transmitter and receiver, ultraviolet waves have been used to carry speech and music for a distance of a hundred feet. Infrared light, quite invisible to the eye, has been used for secret signaling in daylight and darkness.

Production of Radio Waves

The first method of achieving the manufacture of electric waves (1886) took advantage of a phenomenon well known for more than fifty years. In 1827, Savery of France discovered that the electric discharge of a condenser, of which a Leyden jar is a good example, is oscillatory. According to this method two conductors, for example two spheres or two parallel plates of metal, were given a high-voltage charge by means of a static machine or induction coil. When the charge was raised to a high-voltage level, a spark jumped across. Electrical vibrations were thus manufactured.

An analogy may help one to get the idea of an oscillatory discharge. A tall tank of water is connected to another empty tank. A closed valve in the connecting pipe is opened; it might even be broken through by the pressure of the water. Water would rush out of the full tank up into the empty tank and then back into the original tank. There would be a series of water current oscillations. Now the condenser is a sort of pair of electrical tanks. During its discharge electrical currents oscillate back and forth between the two metallic surfaces. As stated, Savary first discovered this oscillatory character of a condenser discharge with a spark visible at the gap. Accompanying the rushing of electric current back and forth, electric waves are radiated. Lord Kelvin first set up and solved the mathematical equations for such electrical vibrations. His explicit mathematics of 1853 still is valid to calculate the frequency and wavelength of electric waves.

This basic method of condenser discharge was the one originally used by Hertz and and later by Marconi. It was the accepted method for radio telegraphy for many years but could not be used for radiotelephony. We now know that the lightning flash is oscillatory; so Dame Nature, using the cloud and the earth or two clouds as plates of a condenser, had the technique before Savary, Joseph Henry (who in 1842 made important contributions in this field), Lord Kelvin, and Hertz.

A second method was that of the rotating electrical dynamo. It is the method which has ever been used for the production of the sixty-cycle alternating current to supply light, heat, and power. High speed rotating dynamo electric machines were designed by Fessenden (1907), Alexanderson and Goldsmidt to produce, for the purposes of radio telegraphy, frequencies in the neighborhood of one hundred and fifty thousand cycles per second, two kilometers in wavelength. These electric waves were very long.

The Era of Electronics

The X-ray was the result of research concerned with the study of electricity in a vacuum. Out of that research and philosophy expressed by Sir J. J. Thomson came that modern Aladdin's Lamp, the electron tube.

The tradition of research on electricity unassociated with ponderable, sluggish, and hampering atoms of matter, on electricity per se performing in a vacuum tube, on electrons, so brilliantly begun by Crookes, J. J. Thomson, Roentgen, Becquerel, Edison, and many others before 1900, has been carried on with equal brilliance by their successors. Fleming, Millikan, Richardson, Carty, Lorentz, de Forest, Arnold, Langmuir, Jewett, and many others have exhibited magnificent international teamwork in putting electrons into useful service.

During the televictorian age of the last years, the limitations of time and space have been erased because electric waves of many lengths and many frequencies have been revealed as pearls without price in nature's bounty. They became a useful reality when an atom of electricity, an electron, electricity its very self was put to work inside a vacuum

tube. Our planet has become "one world" largely because of electric waves. The televictorian age, the electric wave age, and the electron tube age have become synonymous.

First used in a practical way as an amplifier in 1915 at intervals along the telephone line to span the United States, the electron tube has become an essential device in thousands of miles of long-distance telephone lines throughout the world. Contemporarily, it was recognized as a most important actor in both transmitter and receiver in radio telephony, radio telegraphy, and radio broadcasting. Today it is aptly applied to a thousand and one other tasks. Associated with proper electrical wire circuit arrangements and electric power supply, the vacuum tube can generate electric currents; it can also mold electric currents, amplify electric currents, rectify electric currents, and detect electric currents. In many ensembles of high-frequency equipment today, it likely performs all five functions. In its role as an oscillator, as a generator of electrical vibrations for communication, it plays the part of a virtuoso for the manufacture of twenty octaves or more of electric waves. Armstrong, de Forest, Colpitts, and Hartley were pioneers in this field. Many others later made further contributions to the operating techniques and apparatus for the creation of electric waves by electron tubes and associated circuits. In many ingenious designs and forms, the electron tube circuit generates electric waves from sixty cycles per second to 500,000 million cycles per second—in wavelength, from five million meters to six millimeters.

By wire and radio, millions of telephone and telegraph messages are carried each day; electrical echoes, as utilized in the recently announced radar, detect and tell the distance and the angle of the approaching ship or airplane; light waves give vision and carry messages; heat waves transmit warmth and help the earth to be the good earth with its abundant harvest; portable X-ray equipment on the field of battle enables the injured to be restored to health; gamma rays of radium heal wounds; and cosmic rays stimulate the imagination as to the nature of the world in which we live. Electromagnetic waves, long, short, ultra-short, micro and micro-micro—eighty octaves of them—intangible, imponderable, mostly invisible, inaudible, constantly the subject for research and investigation throughout the world, are the talented and versatile members of a most fascinating family now playing a conspicuous role on home fronts and on war fronts.

TROPICAL MEDICINE: ITS SCOPE AND PRESENT STATUS*

By ELLIS HERNDON HUDSON

MEDICAL and lay attention is now being directed toward tropical medicine in unprecedented degree. Admiral Stitt, looking back over the past fifty years, recently traced the curve of interest in tropical medicine through three wars. During the Spanish-American war, malaria, yellow fever, and the dysenteries were to the fore. The subsequent cutting of the Panama Canal, the occupation of the Philippines, and operations in the West Indies kept interest in tropical diseases on a gradually rising curve. The World War of 1914–18, however, was fought—at least by American forces—in temperate zones, and Stitt points out that the focus of medical attention was transferred to meningitis, trench fever, and the pneumonias—streptococcal, pneumococcal, and influenzal. During the inter-war period, for two decades after 1919, tropical medicine made steady progress but was overshadowed by other branches until a few years ago, when it was realized that, for Americans at least, the approaching second world war would be fought to a large extent in the tropics and subtropics. With the establishment of American troops in the Caribbean and Mediterranean basins, in India, China, and the East Indies, and the southern Pacific, the curve of interest has again turned sharply upward.

Is this Country in Danger of Imported Exotic[1] *Diseases?* Anxiety has been expressed lest the contact of American troops with tropical diseases abroad will react unfavorably upon the health of the people of continental America. This anxiety is to some extent justified. The two barriers of time and space which once kept diseases away from our shores have been abolished by the automobile and airplane. We read of a newspaper correspondent leaving Australia on Tuesday and arriving in San Francisco on Thursday, only seventy-two hours later. A Navy man comes to the Washington Dispensary with a sandflea (*Tunga penetrans*) between his toes; he acquired it in South America and returned by air before it manifested its presence. The Pan American Highway runs right through the region of Guatemala to which onchocerciasis (filariasis of the skin) has hitherto been limited. Even Bartonellosis (oroya fever, Carrion's disease), which has been found only in remote valleys of the high Andes, may become a general hazard by reason of military movements and modern methods of travel.

Many diseases which take time to develop used to be detected in travellers before their long homeward voyage was completed; now a man may contract malaria in India or the South Pacific and have his first chill in New York or Denver. From the standpoint of contagious disease new significance is added to the aircraft advertisement which states that no man on earth lives further than sixty flying hours from any American airport. The spread-rate of epidemics, such as dengue, influenza, and cholera, has always been in direct ratio to the rate of human travel; hence, many minds are preoccupied with the possibility of swift and overwhelming pandemics.

Another disquieting feature is that whereas tropical diseases were formerly imported into this country by the occasional "foreigner" or immigrant, they will doubtless be brought in during this war by thousands of our own men who will return to live in their "home-towns" scattered throughout the land. Further, it looks as if our commitments for stabilization and maintenance of peace after the war will involve us in such

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[1] The word exotic—used in antithesis to indigenous—is in some respects preferable to the word tropical. Many of the diseases now called tropical once flourished in temperate zones, and others even today are prevalent in temperate regions other than our own.

responsibilities in tropical countries that a constant stream of such infections will continue to be imported into this country for an indefinite period.

Though these are real dangers they can easily be exaggerated. Some medical and lay writing on the subject has been needlessly alarmist, and the other side of the picture needs to be emphasized. Many tropical diseases, especially of the metazoan parasites, are dependent for their propagation upon habits not found in this country. In this group are the flukes, dependent upon human consumption of raw fish and crabs; the intestinal roundworms, dependent upon the use of nightsoil as fertilizer, and the lack of personal and community hygiene; and the tapeworms, dependent upon human consumption of uninspected meat or the ingestion of food or water contaminated with animal droppings. In other diseases, such as trypanosomiasis, leishmaniasis, filariasis, and schistosomiasis, the vector or the intermediate host is either absent in this country or can be controlled by use of present knowledge or extension of present sanitary measures.

Even in the case of malaria, though new and possibly more virulent strains may be imported, and though there may be sporadic outbreaks, our health-conscious communities and efficient health services will keep the disease local and transient. Indeed, new knowledge of malaria now being gained in this war, in techniques of treatment and mosquito control, will tend to clear up much of the disease already existing on this continent.

There are two other favorable features. After the war many physicians will return to this country armed with experience in the diagnosis and treatment of tropical diseases. And secondly, there is much indirect evidence that temperate zone temperatures and climatic conditions per se have an unfavorable effect upon the propagation of tropical diseases.

In summary, one may well conclude that although the impact of tropical diseases on this country because of the war and its aftermath may be substantial, the dangers to our people can be largely avoided by the use of knowledge and facilities now in our possession. The converse of this fact is that the names and characteristics of many exotic diseases will have become familiar to millions of service-men and their families. Increased lay and medical interest is, no doubt therefore, only the prelude to expansion in this field of medicine in the United States.

The medical schools, while conscious of the present pressure on the medical student and curriculum, and the shortage of teachers, nevertheless recognize the necessity for instruction in parasitic and tropical diseases. In recent months existing courses have been strengthened, new courses have been introduced, special lectureships are being provided, teachers are being trained both in this country and abroad, information about exotic diseases is being pooled among the medical schools, and a distribution center has been established for specimens, pathological material, and visual teaching aids. This increased emphasis upon tropical disease has received the hearty encouragement of the Surgeons General of the Services, who for many years have been concerned with the training of young doctors in this field.

If, as Gregg has said, the next ten years will witness a revaluation and reform of the medical curriculum, the signs indicate that tropical medicine will have gained in stature in the process.

Advantages to be Anticipated from Expansion of Tropical Medicine. Some favorable features will result from this new and growing interest in the tropical field. First will come a greater appreciation of the importance of environment in disease. Earlier viewpoints stressed the static relationship of host, parasite, and environment. Later, fluctuation of both parasite and host was emphasized, but the molding influence of environment was slow to be recognized. Now, however, it is admitted that all three components of the disease picture are fluid entities and that the end result at a given time and place will depend upon their mutual influence. This concept is powerfully reinforced by a consideration of tropical disease, in which environmental and epidemiological factors occupy so prominent a place.

The second gain from the new interest in exotic diseases will be appreciation of the geography of disease, a science still in its infancy. The Germans were far ahead of us in this field, but their knowledge has been

perverted to base uses, political rather than scientific. There are two phases in this branch of medicine: disease distribution in relation to geography, and differences in the *same* disease as it appears at different places on the earth's surface. That is, we shall not only be interested in the "what, where, how, and why" of the diseases indigenous to the jungles of Brazil, the deserts of Africa, and the islands of the Pacific, but we shall also be concerned with the behavior of diseases more familiar to us, such as tuberculosis, measles and cancer, as they occur in the environments of regions so different from our own. Tropical medicine introduces us to the importance of *place* in pathology, and the diagnostic value of the question, where has the patient lived?

Thirdly, the mutual impact of tropical and temperate zone medicine is pregnant with possibilities in the field of research. On the one hand, tropical medicine is ten to twenty years behind in applying the techniques of modern investigative physiology, biochemistry, and pharmacology. Knowledge of the pathology, diagnosis, and treatment of exotic diseases is bound to increase rapidly as these techniques are applied to them. An amazing amount of unknown territory in tropical medicine can be taken over simply by the use of weapons which temperate zone medicine already has in hand.

On the other hand, research in tropical zones will stimulate all branches of medical research, not only because it offers an unlimited quantity of human material for investigation, but because the exaggerated conditions of disease found among tropical peoples will throw light upon the less easily analyzed disorders of temperate zone civilization. One need only point to disorders of the liver and the varieties of anemia found in the tropics, to illustrate the lure which the tropics should have for the pathologist and the hematologist.

In general, it may be truly said that the study of disease in tropical environment lifts horizons and broadens concepts of the reaction between the human body and its would-be invaders. The physician trained in the temperate zone will find use for all the knowledge he already has when he goes to the tropics, but he will have to supplement this after he arrives with often painfully acquired experience which he could never have obtained elsewhere. He will realize that tropical medicine is temperate zone medicine, *plus*. Peripheral edema may not be due at all to nephritis, but to vitamin deficiency; pain in the right lower quadrant may be due to malaria, and intestinal obstruction or asthma may be due to ascarid worms. The Samoans suffer from filariasis but they also die of tuberculosis; the natives of Africa have trypanosomiasis, but they also suffer from the same nutritional deficiencies as the patients in Birmingham, Alabama; the peoples of India and China have leishmaniasis and distomiasis (fluke infestation), but they also die of pneumonia and typhoid.

The Lack of Organized Information on Exotic Diseases. Tropical medicine as it is known today is a composite of facts gleaned from a multiplicity of diverse and unrelated sources. Such a book as McKinley's on the geography of disease gives some idea of the extent of contradiction and discrepancy in our knowledge. Maps of tropical diseases have to be approached with great caution because a blank may mean either that the disease is not present, or simply that it has not yet been looked for and reported. Yellow fever, which for years contracted and faded to minute proportions on the world map, has suddenly blossomed forth to cover large areas of two continents, simply because a new concept of the disease has been established.

Most of the facts about the health of tropical regions come from governmental reports, usually issued annually by the European powers responsible for the various areas. For large tracts of the earth we are dependent on these reports for vital statistics. It is true that they are often defective, their methods and results are frequently not comparable, and much is hidden in unrelated files. Sometimes there is deliberate lack of candor in revealing conditions. Facts can only be secured by patient digging; yet this is the best source for general knowledge.

Other sources of information are the reports of such quasi-governmental organizations as the Health Office of the League of Nations, the Indian Medical Service, and the observations of our own Army in Panama

and the Philippines, and our Navy in Samoa, the West Indies, and elsewhere. In this connection should be mentioned the many national societies of tropical medicine, and the numerous institutes and research centers in tropical countries, such as the widely scattered Pasteur Institutes, the Malaria Research Institute of India, the Oswaldo Cruz Institute of Brazil, the Gorgas Memorial Institute in Panama, and others. There are famous schools of tropical medicine in tropical countries, such as Puerto Rico, Cuba, Mexico, India, Egypt, and Java, and others in great centers of teaching in temperate zone countries, such as London, Liverpool, Paris, Antwerp, Lisbon, Peiping, Melbourne, Boston, New York, and New Orleans. There was once an important center in Hamburg.

There are also the great private and semiprivate foundations such as the Rockefeller, the Leonard Wood Memorial, and the British Empire Leprosy Relief Association. Various universities have sent expeditions to South America, Africa, and elsewhere for the investigation of particular diseases, and other commissions under Red Cross or military auspices have undertaken the study of typhus fever, relapsing fever, pneumonic plague, and other epidemic diseases.

Big commercial companies, representing among others the oil, rubber, and fruit interests, have stimulated the study of tropical diseases in an enlightened spirit of humanitarianism; important contributions have also been made by physicians maintained in tropical countries by missionary societies. These lone workers, and the private practitioners, both foreign and native, in tropical regions, have gathered a mass of information of great value out of proportion to their numbers because of their long periods of residence and their intimate knowledge of language and people.

This catalogue is obviously incomplete, but suffices to bring into relief the patchwork picture of tropical medicine as it now is, and suggests why this field is still so unorganized and unequally developed.

The Content of Tropical Medicine

Medicine in general comprises certain conventional subdivisions such as pathology, symptomatology, and therapeutics. Let us assume these standard disciplines and proceed to examine in some detail the special fields which tropical medicine draws within its ambit.

Helminthology is concerned with the metazoan parasites which inhabit the intestinal tract or the tissues of man. They include the hookworms, whipworms, pinworms, and ascarids; the filariae of skin and lymph tissue; the cestodes, some of them living as adults in the intestine, and others as immature forms in the tissues; and finally the trematodes, the flukes of lung, liver, intestines, and blood.

Protozoology furnishes the next group of parasites, the amoebae, the blood flagellate trypanosomes, the tissue flagellate leishmanias, the spirochetes of treponematosis (yaws, syphilis), leptospirosis, and rat-bite fever, and borreliae of louse- and tick-borne relapsing fevers. This unicellular group also includes the plasmodia of malaria.

The bacteriology of tropical medicine introduces the bacillus of plague, the mycobacterium of leprosy, the vibrio of cholera, the rickettsiae of typhus and spotted fever, and the viruses of dengue and yellow fever.

Tropical *mycology* must not be omitted. Perhaps the discovery of penicillin will stimulate interest in this hitherto neglected subject.

Entomology. Tropical medicine is intensely concerned with arthropod life, for insects and arachnids furnish the vehicles for transfer of diseases, and the reservoir for their maintenance in nature. Animals of other phyla provide intermediate hosts for the propagation and dissemination of parasites. Thus, importance attaches to the distribution, identification, anatomy, physiology, and ecology of mosquitoes and other flies; the fleas, bugs, lice, and ticks; the snails, crabs, frogs, and fish.

Many of the lower orders of mammals share tropical diseases with man, and constitute reservoir hosts for the infections. Illustrations of this are the carnivorous cats, dogs, and wolves in helminthiasis; the wild game of the veldt in trypanosomiasis; the monkeys, marsupials, and edentates in yellow fever. Study of these reservoir and alternate hosts throws light on human diseases, and thus *mammalogy, verterinary medicine,* and *comparative pathology* become integral parts of

tropical medicine. *Herpetology* and the production of antivenins must also be included at this point.

A fascinating and as yet unwritten chapter of knowledge is the evolutionary history of these parasites and their hosts, and their relation to the great *geological* epochs. Tropical diseases are related to the fact that the oases in the Sahara are the last drying remnants of once broad and flourishing jungle. Tropical medicine is interested in the theory that the "nose" of South America once fitted snugly into the concavity of Western Africa (the so-called Wegener continental flotation hypothesis), and the theory that there was once a continent (Lemuria) connecting up India and Ceylon with Madagascar and Africa. The distribution of tropical diseases and their vectors is certainly related to the fact of Wallace's Line which swings through the East Indies and separates the fauna of Asia from that originating in Australia. Knowles has attempted to explain the present peculiar distribution of quartan malaria on geological grounds, and has advanced the view that *P. malariae* was the first of the plasmodia to select man as host. This is only one tentative furrow in an exceedingly interesting field.

The sciences of *meteorology* and *climatology* are admitted to be of increasing importance in medicine. The formation of clouds and winds, the fluctuations of temperature, the distribution of isobars, the amount of precipitation, all have a direct bearing upon the presence and distribution of disease. Change of temperature is a tonic to the human organism, a blessing which the inhabitants of the energizing regions of the world, such as Europe, the United States, South Africa, and the Argentine, have not fully realized. The absence of temperature-swing in tropic zones has a bearing upon the temperament of tropical peoples, and probably contributes to their relative freedom from the so-called degenerative diseases of civilization, the price which men of the temperate zones must pay for the mixed blessing of aggressive energy.

How far, and at what cost, can the white man be acclimatized to the tropics, are questions still to be settled. That he can live there in comfort is proven by experience in Panama, the Dutch East Indies, and elsewhere. But man has only two means of disposing of the heat generated by combustion within himself; namely, radiation and perspiration. Where environmental temperatures exceed 98.6° F., radiation is no longer possible—indeed is replaced by absorption. The body is therefore restricted to the alternative; but loss of heat by evaporation from the skin surface depends upon the ability to sweat, and this also has obvious limits. Man in the tropics is therefore forced to live at a lower level of energy and of oxygen consumption to keep from dangerous accumulation of internal heat. Paradoxically, as Mills has pointed out, the laborer in the tropics turns out less work per unit of time, but is a more efficient machine than the northern laborer.

Nutrition. The science of food elements and requirements finds in the tropics an almost virgin field, a multiplicity of "impressions" and few established facts. In general, the tropical menu is monotonous, and the food not so palatable, so thoroughly cooked, or so finely divided as elsewhere. The appetite craves less of animal foods and more of starches, greens, and fruits, leading to deficiencies in calcium, the B complex, and the animal proteins. Among the minerals, iron is particularly lacking, a fact which leads to various forms of hypochromic anemia.

Rice is the staple food of one half the world's population, and for this portion of the human race it constitutes eighty to ninety percent of the food intake, supplemented in the case of the Arab with dates and locusts, and elsewhere with dried fish and pickled radish. Rice has a good selection of vegetable proteins, but does not furnish all that are necessary for full health, and is deficient in minerals and vitamins.

There is some support for the view that most people in the tropics get less than the optimum intake of the B complex. The B contents of tropically grown foods are definitely lower than those of northern climes, and since B is water-soluble it is lost in the sweat. Further, it has been shown that mice living in a temperature of 90° F. require twice as much B complex per gram of food

as mice living in a temperature of 65° F., and presumably something of this sort is true of man. Since there is close relationship between vitamin B and "resistance to infection," there are grounds for the assumption that natives of the tropics, failing to receive adequate quantities of the complex, are more susceptible to infectious diseases.

In this connection, Cannon has pointed out that food-proteins are essential not only for the formation of normal globulin in the blood, but also for the closely related antibody-globulins. In other words, the ingestion of a full complement of amino acids is essential insofar as antibody production is fundamental to "resistance." Cannon is speaking particularly of the gradual depletion of the body proteins in war and famine, resulting in pestilence in its various forms. But in tropical countries, though the factor of war may be absent, unbalanced diet and chronic famine is a constant specter. Doubtless here also hypoproteinemia results just as inevitably in widespread susceptibility to disease.

Many tropical peoples are slight of build and short of stature. Is this due solely to race, or do climate, nutrition, diet, and other factors also have a role? Krogman quotes Hooton to the effect that height, weight, thoracic dimensions and proportions, and similar bodily features are so directly susceptible to health, diet and food habits, climatic factors, exercise, occupation, and other miscellaneous influences as to render them useless as racial criteria.

Neuropsychiatry. Unquestionably, white men and women going to the tropics undergo considerable psychic trauma. McCartney, who has recently reviewed the subject of tropical neuropsychiatry, predicts that many men in the services will return from the tropics with permanent neuropsychiatric disabilities. Strange environment, foreign language and customs, unaccustomed food, intense light and heat, tropical rains, ubiquitous and exasperating insects, all are factors which, combined with the monotony of existence, the lack of amusements, and restrictions of companionship, lead to neuroses and depressions. Least successful are the egocentric and rigid personalities lacking poise or given to idiosyncrasies and complexes. Most successful are the sanguine, the adaptable and resourceful, and the intellectually curious.

Men and women who have gone to the tropics under the compulsion of commercial, religious, and humanitarian incentives are often able to establish homes which cushion them from the warping impact of the foreign environment. Some, however, fail to adjust, and are invalided home as "nervous breakdowns" or misfits.

Men in the armed services at tropical stations have the advantage of knowing that their period of service will probably be short; they have many companions of their own kind with food and other things from home; their life may be uncomfortable and often dangerous, with few opportunities for amusement and recreation, but it is seldom monotonous for long. But in contrast to these stabilizing factors is the frustrated feeling—often unexpressed—that they are not there by their own will, but in the control of forces which they are unable to influence. There are many in the service ranks of low emotional adaptive power, and in the presence of danger and the natural human reaction of physical fear, it is not surprising that psychiatric casualties are proving to be an important feature of tropical campaigns.

Turning now to other fields in which tropical medicine has an interest, we come to *ethnology* and *anthropology*. Many of the advances in both these sciences have been made by physicians working among the natives of tropical regions. Customs, religious rites, and social organizations have a bearing on health. In Moslem countries the necessity for ablutions leads to pollution of the river banks, and the pilgrimages to Mecca tend to spread disease. In India the great fairs and festivals, the veneration of the cow, and the respect for insect life create problems in the control of disease. In many countries patriarchal and tribal organizations make enforcement of health laws difficult. The importation and traffic in slaves have always been a feature of the spread of disease in tropical countries. It is of particular interest in connection with the export of slaves from Africa through Abyssinia to

Arabia and the East, and the importation of black slaves and their diseases into the New World.

No one will deny that tropical medicine has a vital interest also in the development of the *economic* and *political* life of the tropics, not only for the acclimatization of the white man, but in the inevitable future industrialization of wide regions still undeveloped. The resources of large areas have only been touched. There is, for example, more water power in the single basin of the Congo than is harnessed at present in the *whole* of the United States. Political organizations, such as colonies, mandates, international trustees or hitherto untried devices for native development, must be buttressed by health schemes of a magnitude as yet not attempted. Whole diseases must be eradicated, and effective barriers erected to prevent the spread of diseases to new regions of the earth along lines of travel and commerce. Imaginative planning will have to be done in terms, not of nations, but of continents and the globe.

This discussion has presented two challenging facts, namely, that tropical medicine is a rapidly expanding field, and that few of the sciences can afford to refrain from interest and participation in this expansion. If the medical world has the wit to draw on all these ancillary sciences, and if these sciences have the wisdom to see what opportunities for them lie in the matrix of tropical medicine, new and exciting vistas will open both for the advancement of abstract knowledge and for the improvement of man's health, as dividends accumulate from this cooperative activity in the tropics.

MALARIA CONTROL

WAR correspondents have reported that the Battle of Bataan was lost, not because the ammunition was gone, but because the quinine tablets gave out. Ten days before the end, 80 percent of the front-line troops were suffering from malaria. When the Japanese extended their advance to the south, America lost both her rubber and her quinine. Fortunately as far as quinine was concerned, synthetic chemistry jumped into the breach, but with the war extending into malaria-infested countries all over the world there is still great need for a drug that is better than quinine or any available quinine substitute. Indeed among war diseases malaria ranks ahead of typhus and influenza in the list of unresolved problems.

Over many years, and in many countries, The Rockefeller Foundation has worked in the field of malaria. During the earlier period its activities were largely confined to various methods of mosquito control, such as drainage, screening, the use of fish to destroy mosquito larvae and the employment of sprays and Paris green. But in many parts of the world these measures are inapplicable for economic or physical reasons. In such areas the widespread use of drugs is at present, and particularly under war conditions, the only feasible means of control.

The use of drugs, however, has been shown to be largely ineffective, even under the most favorable circumstances, because of two fundamental disadvantages inherent in the drugs now in use. In the first place, these drugs do not always eradicate the infection, and thus a constantly increasing carrier reservoir accumulates, tending to spread the disease. In the second place, the drugs cannot be wholly relied upon to prevent the development of malaria following the bite of an infected mosquito.

These disadvantages assume even greater importance in wartime than under normal conditions, because the introduction of large numbers of nonimmune persons into malaria-ridden countries naturally increases the incidence of the disease. The development of some new drug, not subject to the limitations of quinine and its substitute, would have enormous military and public health significance. . . .

The [Foundation] campaign in Brazil . . . was successful in driving out a particularly dangerous malaria mosquito imported from Africa and called *Anopheles gambiae*. It is a pleasure to report that there was no reappearance of gambiae in 1942 in the area in which the campaign was waged. But although the gambiae is driven out of America, this is not the end of the story. There remains its homeland. The bad reputation of Africa as the Dark Continent is based in part upon the exceptional activity of this mosquito. . . . The gambiae holds firmly in its grasp whole areas, from Dakar in the west, straight across the Continent, and all the way south. Unless this mosquito can be exterminated, or its effects neutralized, it does not seem probable that the vast regions which it now contaminates can be successfully developed.—*Raymond B. Fosdick, in "The Rockefeller Foundation-Review of Work in 1942."*

NEWTONIAN AND OTHER FORMS OF GRAVITATIONAL THEORY*

I. NEWTONIAN THEORY

By GEORGE D. BIRKHOFF

It has been generally granted that Sir Isaac Newton's work on universal gravitation constitutes an unsurpassed scientific achievement. To begin with, in order to develop his ideas concerning the nature of gravitation, Newton devised that necessary mathematical instrument of modern scientific thought, his "fluxions," now termed the calculus; then, with the aid of this powerful new tool, he developed the principal theoretic consequences of his inverse square law; furthermore, he applied his theory to the most varied types of gravitational phenomena with extraordinary skill and penetration; and, finally, after making certain that supposed observational discrepancies were disposed of, and after transferring his analytical equations into the language of infinitesimal geometry current in his day, he gave out his great master work, the *Principia* of 1687. Truly this four-fold accomplishment was most remarkable; and the unfoldment of the program for the physical sciences which Newton thus initiated has continued to dominate the field of physics during nearly all of the two and a half centuries which have since elapsed:

> Nature and Nature's laws lay hid in night.
> God said "Let Newton be," and all was light.

In this tercentenary year (1942) of Newton's birth it is therefore natural and appropriate to estimate his theory of gravitation in its relation to the new forms of gravitational theory which have developed in the last four decades. This I shall endeavor to do in what follows, avoiding the use of technical mathematical terms except in a purely descriptive way. Likewise when simple equations are written down in a few cases, it is only to show the obviously close formal analogy between the Newtonian theory and its modern counterparts.

It should be remarked first of all that not until after the celebrated Michelson-Morley experiments of 1887 did it begin to be realized that matter was astonishingly indifferent to motion through the ether. Between Newton's discovery and these experiments there had elapsed more than two hundred years. In this period physicists and astronomers did little more than consider the following questions concerning gravitation: Is it not possible that gravitation travels with a finite velocity instead of with infinite velocity as demanded by Newton's theory? Is it not possible that an exponent slightly different from the exponent 2, appearing in his law, might improve the theory? Are or are not "inertial" mass and "gravitational" mass exactly the same, as was postulated by Newton? The careful study of these three questions had only served to confirm the Newtonian theory.

Aside from this specific work, one fact, however, had emerged: A very close examination of the phenomena of the solar system by theoretical astronomers, on the basis of the Newtonian law, had shown that there was a slight but definite excess of perihelial advance of the planet Mercury amounting to 41″ per century. Since the velocity of Mercury is large as compared with the velocities of the other planets, it was natural to conjecture that here was beginning to appear a deviation from the Newtonian law which should become more and more marked as the velocity approached that of light, which is the fundamental limiting velocity in an electromagnetic universe.

The analysis here undertaken will begin with some simple mathematical observations and then pass on to give an outline of the Newtonian theory (part I) and of recent

* From the symposium on "Natural Philosophy" commemorating the 300th anniversary of Newton's birth which was to have been presented at the New York meeting of the American Association for the Advancement of Science.

relativistic theories of gravitation (part II). My approach will in no sense be historical.[1] Instead, it will present a comparative analysis of the various forms of gravitational theory. The Newtonian theory of gravitation may be likened to the opening movement of a great scientific symphony, expressed in the natural language of everyday geometrical and temporal intuition, namely that of 3-vectors. There follows an analogous second movement formulated in the terminology of 4-vectors, appropriate to 4-dimensional "astro-electric" space-time. In this, Nordström's gravitational theory of 1912 appears as the natural development, although ending in an unresolved discord because certain slight gravitational phenomena, like that observed in the motion of Mercury, are not accounted for. Then there follows immediately the very brilliant, chaotic, and incomplete third movement formed by the gravitational theory of Einstein of 1916. Here the calculus of tensors, appropriate to space-time curved by matter, is employed throughout. In this way the discord in the second movement is resolved and the predictive power of the new theory is established.

Now it has been generally agreed that (to carry our musical comparison a step further) there is need for an appropriate coda. Weyl, Kaluza and others have shown that there exist interesting possibilities in the way of providing a unified account of electromagnetic and gravitational phenomena. To these I shall refer only briefly. But I shall characterize more in detail a recent attempt of a fundamentally different type, which I presented at the Astrophysical Congress which met at Puebla and Tonantzintla, Mexico, in February, 1942.[2] My theory, like that of Nordström, is based on the simpler Lorentz-Minkowski space-time of electromagnetism.

It is entirely too early to say as yet how any of these various theories will be regarded in the future. One may well doubt whether any known physical theories will have final validity for the comprehension of Nature. We can be quite certain, however, that the classical Newtonian theory of gravitation will always remain serviceable to the theoretical astronomer. Indeed, from this point of view, a more complicated gravitational theory, like that based on a curved space-time, can only operate as an "auxiliary construct" (to use Larmor's characterization), taking into account a few minute relativistic gravitational effects almost beyond the reach of observation.

Of course, it is impossible to understand and appreciate adequately the magnificent work of Newton without proper historical perspective. It is easy but misleading to magnify his position at the expense of his contemporaries and predecessors. Perhaps the half dozen figures of greatest import in the Newtonian background are those of Archimedes, Galileo, Kepler, and Descartes among his predecessors, and, among contemporaries, his illustrious friend, the "Summus Hugenius," and his yet greater rival, the mathematician and philosopher Leibniz. Furthermore it must be admitted that both the calculus and the classic theory of gravitation lay quite near at hand when Newton found them. This is evidenced by the fact that Leibniz was a co-inventor of the calculus, and by the prevalent discussion of a possible force of attraction inversely proportional to the square of the distance.

Our point of view will be mathematical rather than physical, in the following sense. The physicist as such disclaims interest in any theory which is not in accord with Nature, even though it has achieved a considerable degree of success. At each moment he is hoping to discover the ultimate, all-embracing theory, after which he expects to abandon forthwith the earlier partial explanations. On the other hand, the mathematician studies freely all forms of theory which possess a certain esthetic-mathematical quality. Thus he is not only interested in ordinary real numbers, but invents imaginary numbers and a host of other types of number which interest and fascinate him as objects of abstract thought. Often he finds later on that these generalizations and modifications turn out to be essential for the understanding of natural law. Thus, to take

[1] For an extremely interesting historical and scientific evaluation of Newton see E. T. Bell, "Newton After Three Centuries," *American Mathematical Monthly*, November, 1942.

[2] To be published in the Proceedings of the Congress.

a recent striking example, in quantum mechanics it has been necessary to deal with "matrices," which constitute a kind of generalized number previously studied in detail by mathematicians for their own sake. Likewise mathematicians have studied many forms of geometry, and in particular the general n-dimensional Riemannian geometry of curved spaces; and only by use of this theory and the associated mathematical theory of tensors of Ricci and Levi-Civita was it possible to develop the consequences of the "equivalence hypothesis" which lies at the basis of the generalized theory of gravitation of Einstein.

In what follows, then, the esthetic-mathematical point of view will be taken throughout. Moreover, we shall not venture to conjecture what the ultimate account of gravitation is going to be, but rather we shall try to coordinate and appreciate the formal structures of various gravitational theories, as well as to assess their serviceability in physics.

The Use of Models in Mathematics and Physics. From the beginning of his scientific thinking, man has progressed by means of conceptual models taken from Nature. In fact, from a certain point of view, mathematics itself, crudely defined as the study of number and form, takes its origin in this characteristic way. For, the simplest type of physical universe is one thought of as made up of classes of distinguishable objects, considered without regard to their specific properties but only as comparable with one another by the process of matching or one-to-one correspondence, as when the fingers of one hand are matched with those of the other. Through experience with this simple universe of classes, the concepts of logic and number arise irresistibly. Likewise the type of idealized universe in which there are rigid bodies comparable with one another by direct superposition leads us inevitably to the concepts of Euclidean geometry.

In both of these simple conceptual models so fundamental for mathematics, the complementary processes of Analysis and Synthesis, which Newton insisted were necessary for mathematics and physics alike, are obviously present. The intimate intermixture of these two types of processes in his daily experience with number and form has led man to assign to these ideas an absolute and eternal validity not readily granted to other conceptual ideas. Although we no longer think of Euclidean geometry as incorporated exactly in real space, nevertheless Logic, Number, and Geometry are firmly established as basic theoretical constructs of the human mind.

The point of view will be taken in the present paper that conceptual models are likely to continue to play a fundamental role in the development of theoretical physics, despite the apparent abandonment of such models in recent quantum-mechanical advances. All of the gravitational theories to be considered here rest upon the basic model of an underlying space-time continuum of four dimensions, whose "points" correspond to events.

The Role of Postulates. It was because the Newtonian Law of Gravitation was so deeply consonant with the simple intuitive ideas of space and time, as well as with all the known physical facts of his day, that Newton was able to affirm *"Et hypotheses non fingo"*—I do not frame hypotheses! Leibniz had a similar feeling. Said Leibniz, "Far from approving the acceptance of doubtful principles, I would have people seek even the demonstrations of the axioms of Euclid."

From the more sophisticated logical point of view of the present day, it would be considered, however, that all physical and mathematical theories are necessarily built upon certain hypotheses, or "postulates," which need to be carefully stated. In Newton's *Principia* his celebrated gravitational hypothesis is introduced through an analysis of known physical facts, in particular of the consequences of Kepler's planetary laws of elliptic motion. We may synopsize the set of postulates which Newton tacitly employed by saying that he accepted the workaday conceptual ideas of Absolute (Euclidean) Space and Absolute Time, although he saw no reason to distinguish between the Absolute Space and any other space in uniform translatory motion with respect to it, nor to fix upon theoretic units of space or time.

This means for us today that all of Newton's concepts were such as to be best expressed in the mathematical language of 3-vectors (that is, vectors with three com-

ponents). For example, a velocity u is a directed quantity of this vectorial type, since to determine it we need only specify a directed line or vector, showing the direction and magnitude of the velocity in ordinary three-dimensional space.

In what follows we shall see how the Nordström theory referred to above is highly analogous to the Newtonian theory, except that the language has been changed to that of 4-vectors. Furthermore, we shall find likewise that the generalized theory of Einstein is highly similar in structure. Here the appropriate language is that of tensors.

Groups, Invariants, and Mathematical Language. For the deeper understanding of all these theories, it is necessary to say something about the mathematical concept of a "group of operations." If any two or more of the operations can be combined into a single resultant operation of the same type, and if there always exists an operation of the set which undoes what another operation does, then the collection of operations is said to form a "group." It is furthermore found to be convenient to regard the operation which does nothing, called the "identity" operation, as an element I of the group. Thus the postulates for such a group are essentially the following in concise form:

I. $(AB)C = A(BC)$ for any A, B, C,
II. $AI = IA = A$ for any A,
III. $AX = B$ has a unique solution X for any A, B.

The table showing the result of combining any two of these operations constitutes the so-called "multiplication table" of the group.

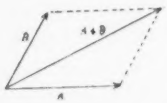
For example, if we consider a square lying on a table and the operations of rotating the square into itself upon the table, we find that there are four operations: the identity I; a rotation through 90°, A; a rotation through 180°, B; and a rotation through 270°, C. The corresponding multiplication table is obviously the following:

	I	A	B	C
I	I	A	B	C
A	A	B	C	I
B	B	C	I	A
C	C	I	A	B

Another very elementary example is furnished by the operations of adding an integer (to a number). Here the identity operation I is that of adding zero.

Now in the geometric background of Euclidean space, the group of rigid motions has always entered intuitively. It will be recalled that Euclid accepted the proof of geometric theorems by the method of direct superposition. This really meant that he was accepting the group of motions as valid in elementary geometry. The natural analytic language in which such geometric ideas are appropriately couched is that of 3-vectors already referred to above.

In this mathematical symbolism certain simple processes turn out to be fundamental. The simplest of these is the multiplication of a vector by a constant which changes the magnitude of the vector by this factor without modifying its direction. Another simple process is that of vector addition portrayed in the following figure. Still another important idea is that of the "scalar product" of two vectors; if these vectors are f and g, this would be indicated by $f \cdot g$. A "scalar" quantity is one, like that of mass, which is essentially a magnitude without direction. The simplest types of quantities in vector theory are vectors and scalars. More complicated but fundamental types are those termed bivectors, dyadics, triadics, etc., by Gibbs. The simplest vector operations, involving the calculus, are indicated by div (read divergence), grad (read gradient) and curl. We shall not endeavor here to define these basic operations.



Two extremely important related concepts in the theory of groups are those of invariable properties and of invariants. In the illustration above of the group of rotations taking a square into itself, an invariable property is that of the adjacency or oppositeness of sides and vertices: evidently adjacency and oppositeness are qualities not affected by performing any operation of the group. Similarly, in the case of the additive

group of integers, the difference of two numbers, $x-y$, expresses an invariant in the technical sense, because this difference is not affected by adding the same integer to both x and y.

In the case of the group of motions of Euclidean geometry, the most fundamental variant is the distance between two points, which is not affected by any motion whatsoever. Riemann showed how this concept of distance appropriately extended lay at the foundation of n-dimensional geometry, whether flat or curved. A somewhat less fundamental concept, but still having great importance, is that of the angle between two lines or vectors. It may be shown that in general the invariants of any group determine the group completely.

Newton really accepts, as the underlying group in his physical theories, this group of rigid motions augmented by uniform translatory motions in time. This imposes a tacit esthetic requirement upon the whole Newtonian development.

The simplest illustration of the expression of a Newtonian law in vector terms is that conveyed in the familiar statement that the resultant of two forces acting upon a point is the vector sum of the two constituent forces.

It is also true that in the later gravitational theories there exists a specific underlying group which to a large extent predetermines the form which the theory may take. It is for this reason that the comparative study of gravitational theories is possible.

On Mathematical Consistency. Physicists have never worried much about the question of mathematical consistency. For example, in the heyday of classical physics, solids were thought of as having a possible type called the perfect elastic solid. The articles and treatises concerned with such elastic bodies never considered the fact that the mathematical theory itself would fail under certain conditions. Thus, suppose that two perfectly elastic spheres were to collide with one another along their line of centers with a relative velocity greater than twice that of the disturbance velocity (that is, the "velocity of sound") in the medium. Then it is true that the basic differential equations of motion themselves become completely useless and the theory of elasticity breaks down. But this fact was hardly mentioned as of any interest whatsoever. The whole history of physics up to the present day shows a disregard of this question of mathematical consistency.

Now it is characteristic of the mathematical point of view here advanced that such inner consistency is held to be a *sine qua non* in a successful theory. In what follows I shall keep this requirement in the foreground, although doing so introduces considerations which most theoretical physicists would consider as of little importance.

Mysticism in Physical and Mathematical Thought. The developments of the last fifty years in mathematics and physics have involved in ever-increasing measure semi-mystical considerations growing out of a highly developed sensitivity as to the role of formalism. It is well to say something about these matters before taking up the consideration of Newtonian and other gravitational theories.

From Newton onwards, theorists in the field of physical thought have tended towards opinions of an intuitive type which constitute an essential directive element in their creative work. In fact, it seems to be true that long-continued and intensive study in any scientific field always leads to vague ideas which are felt to be of basic importance for deeper understanding. The concept of energy was initially of this type. Many other instances might be given.

An important mystical idea of this kind was that the laws of nature can always be formulated by means of some "Variational Principle" or "Principle of Least Action." For example, it was found that a ray of light passing through a medium with variable index of refraction follows the path of least length in time in going from a point A to a point B of the body. To an astonishing degree it was discovered that dynamics and classical electrodynamics admit of very condensed mathematical expression by means of an appropriate variational principle. Even today the physical theorist likes to show that a new theory can be expressed in variational form.

As a mathematician I would like to point out that the significance of such a principle is not what it is often taken to be, for the fol-

lowing reasons: In formulating a mathematical problem there is always a large degree of freedom of choice, both in choosing the independent and the dependent variables. There are likewise a great variety of ways of combining a system of equations into equivalent systems. Because of these facts, it is not surprising that one can manage to obtain a variational principle appropriate to almost any physical or mathematical theory. It is certain at least that theories formally reversible in time, such as gravitational theories, will yield to expression in this variational form.[3] Thus variational methods need to be carefully scrutinized.

Another important principle which has been effectively used by the physicist is the Principle of Sufficient Reason, which lies at the center of Leibniz's philosophical speculations. As I have tried to show elsewhere,[4] this principle is closely related to the theory of groups, and its significance may be conveyed in the following symbolic diagram:

		Principle of		Theory of
Metaphysics	⟷	Sufficient	⟷	Ambiguity.
		Reason		Groups

Perhaps one elementary but typical illustration of the use of this Leibnizian principle in physics may be mentioned. Suppose that two equal forces act upon a point. Because of the ambiguity associated with the relevant group of motions, it is clear that the resultant force must not only lie in the plane of the lines of the two forces but necessarily falls along the bisector of the angle which they form.

It is such principles as the Principle of Least Action and the Principle of Sufficient Reason which have led many of the foremost physicists to adopt a somewhat mystical attitude toward the physical universe. There is no doubt that a large part of speculative physics up to the latest period can be conveniently interpreted in terms of these principles. If we conjecture with Plato that the Deity continually geometrizes, it seems almost certain that the language of Deity will involve the theory of groups and the corresponding Principle of Sufficient Reason on the one hand, and Variational Principles on the other!

An extreme but characteristic expression of the mystical attitude towards physical thought, and of confidence in the unlimited power of the mathematical symbol, is that of Eddington when he says in his *Relativity Theory of Protons and Electrons* (1936):

> Unless the structure of the nucleus has a surprise in store for us, the conclusion seems plain—there is nothing in the whole system of laws of physics that can not be deduced unambiguously from epistemological considerations. An intelligence, unacquainted with our universe but acquainted with the system of thought by which the human mind interprets to itself the content of its sensory experience, should be able to attain all the knowledge of physics that we have attained by experiment. . . . For example, he would infer the existence and properties of radium, but not the dimensions of the earth.

Perhaps such ideas, which are held by nearly all physicists in one form or another, merely indicate a belief that all physical theories are ultimately expressible in simple unitary mathematical terms.

In what follows an endeavor will be made to state certain vague ideas concerning the differing gravitational theories, which are important for their philosophic evaluation.

The Framework Based on the Rigid Body and Ordinary Time. The Newtonian theory starts out with the framework of space and time suggested by daily physical experience. All about us there are rigid bodies which need to be compared and measured. In this way we arrive at the concepts of geometry, and of a space at first attached to the earth, and later on attached to the fixed stars.

Likewise, the notion of time as measured by clocks becomes more and more definitely established on an intuitive basis. Events are thought of as happening when seen, so that the concept of absolute simultaneity is firmly established.

These ideas of space and of time are embodied in the concepts of Euclidean space and of ordinary time. In this space the point of reference, the direction of the axes of reference, and the specific units of distance play no essential part; and likewise, the choice of the instant of time, called the epoch, from which time is measured and of the unit of time has no special importance. Furthermore, as was noted previously, there is an

[3] See my *Dynamical Systems* (New York, 1927), in particular Chapter IV.

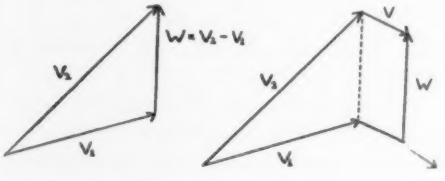
[4] *The Principle of Sufficient Reason*, The Rice Institute Pamphlet, Jan., 1941, pp. 24–50.

additional degree of relativity in that any system moving at uniform velocity of translation with respect to the system of reference is regarded as a valid reference system.

The Underlying Group and its Two Invariants. There would be no object in specifying here in symbolic form exactly what the corresponding group is; it suffices merely to say that if we have given any one set of space coordinates x, y, z, and time coordinate t, there is a large variety of other sets of space coordinates x_1, y_1, z_1 and time coordinate t_1 which are equivalent in a physical sense to the given system of coordinates, namely the sets attached to other systems relatively at rest or in uniform translatory motion.

The fundamental invariants of this Newtonian group are two in number: the distance between two points at the same time; and the interval of time between two events. In fact, the Newtonian group is precisely the most general group which leaves these two quantities invariant.

The Corresponding Language of 3-Vectors. As has been noted before, the language of 3-vectors is that which is appropriate to this type of group, but there are certain restrictions of which at least one should be noted: To say that two vectors are equal is evidently an invariantive statement, since if two vectors are equal in any one coordinate system, they will be equal with reference to any other system whether relatively at rest or in uniform translatory motion. On the other hand, the vector velocity has no invariantive characteristics, since the vectors with respect to one system may not be the same as with reference to another system. This circumstance explains why it is that velocities never appear directly in the Newtonian mechanical and gravitational theories. However, the difference of two velocities is invariant in character, as may be seen from the following figure.



Here the difference of two vectors v_1 and v_2, is indicated, first, with respect to the given system of reference and, secondly, with respect to a moving system impressed with an additional velocity v. It is seen that the final difference w is the same in both cases. Now the concept of acceleration is essentially one involving differences of velocities, and thus is explained the extraordinary importance of the concept of acceleration and its nearly equivalent concept of force in the dynamical theories of Newton.

More explicitly, the force exerted on a body is measured by the product of its mass and its (vector) acceleration, that is, by $M\ du/dt$ where M is a scalar invariant called the mass and du/dt is the notation of the calculus for the (vector) rate of change of the vector velocity u along the path of the mass in question.

The Particle Model of Newtonian Gravitation. Imagine now a system of any number of mass particles in otherwise empty space. For simplicity, we may consider first the case of only two particles of given masses m_1 and m_2.

The Newtonian law states that the force which either mass exerts on the other acts along the line joining the two particles and is inversely proportional to the square of the distance between them; in *absolute* gravitational units of mass the force is precisely equal to the product of the masses divided by the square of the distance. We always employ such absolute units in what follows.

It is evident that this formulation is in accord with the underlying Newtonian group and is as simple a formulation as can be conceived if the force is to tend to disappear as the distance between the two particles increases indefinitely. It is true that it is natural to consider the exponent 1 as well as 2. But the analysis by Newton of the known Keplerian laws of motion in two body motion showed that the exponent must be 2.

When more than two particles are present the resultant force on any one of them is simply taken as the vector sum of the forces of attraction of all the other mass particles.

This idealized model of the solar system has explained practically completely the facts of observational astronomy and predicts correctly the future motion of heavenly bodies to a remarkable extent. Laplace and

other eminent later astronomers have verified the Newtonian theory in more and more detail.

The "Cosmic Dust" Model. In order to explain gravitationally the flattening of the earth at the poles, tidal motion, etc., it is necessary to extend the particle model so as to embrace rigid, elastic, and fluid bodies. Newton began this process of extension by proving that homogeneous rigid spheres would attract one another according to his theory exactly as though their masses were concentrated at their centers. By proving this basic theorem, he was able to reduce this model to that of the simpler particle model. There is no theoretic difficulty in applying the Newtonian theory to any given type of matter, since, according to Newton's law, the known gravitational forces are merely superimposed on the other forces.

Unfortunately, the rigid body model is absolutely out of place in a relativistic theory of gravitation. A simpler type of model which is serviceable in other cases, however, is that of inchoate matter formed by cosmic dust. The state of such cosmic dust is thought of as characterized by its density and vector velocity at each point, each of the particles being attracted towards all the other particles in accordance with the Newtonian law. This model is especially convenient since it enables one to compare directly the recent relativistic gravitational theories with that of Newton.

With this cosmic dust model we have only to state the following two requirements of Newtonian gravitation in mathematical form, using the appropriate language of 3-vectors: mass is conserved; the acceleration of each point is in accordance with the limiting form of gravitational law obtained by passing from the case of many small particles to the limiting case of a continuous distribution of matter. These turn out to be fully expressible in the following abbreviated form:

$$\frac{\partial \rho}{\partial t} + div\ \rho u = 0,$$

$$\frac{d(\rho u)}{dt} = \rho\ grad\ g,$$

$$div\ grad\ g = -4\pi\rho.$$

Here ρ designates the density, u stands for the vector velocity, and π is the familiar ratio of the circumference of a circle to its diameter. The last written equation is called Poisson's equation, and the function g which enters is called the gravitational potential and is required to be zero at infinity.

These equations are written down because they serve to show how the appropriate language of the calculus and of 3-vectors yields the essence of a grandiose and extensive theory in extraordinarily abbreviated symbolic form. It will be especially instructive as we proceed to compare visually this symbolic form with the related symbolic forms of the other theories of gravitation.

Physical, Philosophical, and Mathematical Difficulties. Despite the tremendous successes scored by the Newtonian theory, there are certain inherent difficulties which remain to be mentioned.

Firstly, as noted above, there are delicate gravitational effects, just within observational range, which the Newtonian law of gravitation does not account for.

Secondly, certain natural philosophical requirements are violated by the theory. For example, this law assumes that gravitational forces are transmitted instantly, whereas elsewhere in nature it appears that interaction between distant bodies is always propagated with finite velocity across the intervening space. Newton himself was aware of this grave difficulty of his theory.

Furthermore, gravitational forces are declared to be merely superadded to the other natural forces. Thus gravitation appears as a kind of afterthought on the part of the Creator!

Moreover, according to this theory, there might be a single rotating body. From the philosophical point of view, however, it appears unreasonable to think that, if there were only a single body in the universe, it could be rotating. For with respect to what would it rotate? Nevertheless, according to Newtonian theory this could be the case.

In what follows we shall merely mention similar general philosophical comments. The following fact should always be borne in mind in this connection: ***There are many plausible philosophical demands, and yet no***

conceivable theory can satisfy them all since they are often mutually contradictory.

Thus, for example, it is natural, on the one hand, to suppose that matter somehow conditions space. But it also appears almost inevitable to think of events as transpiring in an invariable framework of space and time.

Under these circumstances it is wise to preserve a certain humility of spirit and not to insist too much upon specific philosophic requirements!

There are also some mathematical difficulties in the Newtonian theory, in particular as applied to the "particle" or the "cosmic dust" model.

In the case of the model based on particles, the difficulty arises at collision. As long as only two of the mass points collide, it is possible to determine mathematically the subsequent development of the system in a unique and natural manner. However, it appears that when three or more particles collide simultaneously, there is a mathematical indeterminateness in the subsequent motion. Such indeterminateness seems objectionable in a physical theory based on the concept of causation. From this point of view the particle model has an unquestionable defect.

Likewise the model based on the type of matter called cosmic dust presents its own special difficulties. In fact a dust cloud will from time to time overlap itself, when different parts interpenetrate; this would not take place if there existed elastic pressure. Even worse, a three-dimensional cloud of dust may be turned inside out as time elapses: Suppose that in a spherical cloud all of the points are moving towards the center with a velocity proportional to the distance from the center. The cloud would then condense to a point at a certain instant and continue as an expanding spherical cloud, but "inside out."

If, however, we introduce a homogeneous adiabatic fluid or gas, with a pressure p and density ρ which are functionally related as in a perfect gas, there will still exist a similar possibility of indeterminateness, namely when two portions collide at a relative velocity more than twice the disturbance velocity.

There is, however, an artificial kind of mass particle which avoids these difficulties. If we suppose that the force of interaction between two particles is one of mutual repulsion at small distances, then collision may be impossible. This would happen if, for example, besides the Newtonian force of attraction proportional to the inverse square of the distance, there were a further force of repulsion proportional to the inverse cube of the distance.

Unfortunately, with this type of model, instead of the excessive perihelial advance which is found in the case of Mercury there would be a regression. Furthermore the modified theory would be definitely less elegant than that of Newton, since the particles would no longer be characterized physically by their mass alone.

(*To be concluded*)

THE AFRICAN ORIGINS OF THE AMERICAN NEGRO AND HIS ETHNIC COMPOSITION

By M. F. ASHLEY MONTAGU

It is the purpose of this paper to analyze and evaluate the available published material which relates to the African origins of the American Negro and his ethnic composition. While this is the principal purpose of the present contribution, some endeavor will be made, in the light of this material, to predict some of the possible trends which the ethnic composition and genetic development of the Negro population in the United States are likely to follow. Our first task will be to determine what is at present known concerning the origins of those Negroes who were brought to America from Africa. Our second task will be to determine the kind and the degree of the ethnic intermixture which the American Negro has undergone since his arrival upon these shores.

Popular Beliefs

It is a common belief that the American Negro represents a mixed population which was drawn from practically every part of Africa. Du Bois, for example, pointing out that the slave trade must have cost Africa in the vicinity of 100,000,000 souls, adds that "Such a large number of slaves could be supplied only by organized slave raiding in every corner of Africa." He goes on to make the comment, "The natural desire to avoid a painful subject has led historians to gloss over the details of the slave trade and leave the impression that it was a local west-coast phenomenon and confined to a few years. It was, on the contrary, continent wide and centuries long and an economic, social, and political catastrophe probably unparalleled in human history." In a more recent work a very similar viewpoint is expressed, namely, in Edwin R. Embree's *Brown America* (New York, 1933). The author writes:

> The slaves were by no means of uniform lineage. They represented tribes as divergent as the several peoples of Europe. They were captured from provinces covering large parts of Central and Western Africa: Guinea, the Ivory, Slave and Gold Coasts, a great part of what is now French West Africa, the vast stretches of the Niger Valley, the Cameroons, the Congo, and Benguela. Among them were Arabs and Moors from the northerly coasts, the small yellow Hottentots from the South, and Bantu tribes from the equatorial regions, although most of them were the large-bodied blacks from the huge area called Guinea. For four centuries the great commerce in slaves ranged over four thousand miles of African coast, from the Senegal River on the north to the southern limits of Angola, and reached up a thousand miles or more inland.
>
> The early manuscripts record the greatest diversity in the African peoples dealt with. . . ."

While there may be some truth in claiming such a universal provenience for the African origins of the American Negro, the evidence at present existing by no means justifies such blanket claims. Far from being even partially solved, the African origins of the American Negro constitutes one of the most glaring of the unsolved problems relating to his history. The present writer has little doubt that, when the subject receives the attention it deserves, a claim such as that made by Embree will be found to be substantially justified, but until the evidence has been made available and critically examined, it were unwise to grant such a claim any status other than that which it deserves, namely, that of a reasonable supposition rather than a demonstrated fact.

Historical Introduction

Since the history of Negro slavery prior to the discovery of the New World is of some relevance for an understanding of the factors relating to the introduction of the Negro into America after its discovery, a brief account of that subject may be given here.

Slavery as an institution in Africa itself appears to have been established long before the dawn of written history. The practice of intertribal raiding for slaves, and the trade in them, is a very old African institution. We know that the Egyptians, from the first to the last Dynasties, utilized Negro slave labor, and the facts all indicate that the

Egyptians themselves secured slaves by warfare and raiding, and at other times obtained them by trade. It is quite clear that Cyrene and Carthage supplied Egypt with a continuous stream of slaves from Africa. It was only with the increase in the Fellahin class and the consequent supply of cheap labor that the amount of slave labor employed in Ptolemaic Egypt greatly declined. In Crete, Greece, and Rome, Negroes were enrolled in the army and were enslaved as domestic servants.

The modern trade in slaves actually had its inception in the Mohammedan conquests in Africa in the seventh century of our era; but it was not very much earlier, if at all, than the twelfth century that Negro slaves were expatriated from the continent of Africa. During the conquest of Spain and Portugal the Moors, from 1195 onwards, brought with them many Negro slaves. Indeed, it appears to have been the Moors who familiarized the Spaniards and the Portuguese with the institution of slavery. Except for the fact that some Negroes appear to have been brought from Africa by some Spanish adventurers during the latter part of the fourteenth century, definite evidence of the arrival in Europe of Negroes as slaves from Africa is not available until the year 1442, when Antem Gonsalvez, a Portuguese sailor, took back with him to Lisbon ten Negroes who had been seized at Rio de Oro on the northwestern coast of Africa. It is by some stated that these Negroes were presented by Prince Henry to the Pope, while others state that they were sold at Lisbon, with the result that numbers of Gonsalvez's fellow-countrymen fitted out expeditions which, in the course of the succeeding fifty years, brought many slaves to the Hispanic peninsula.

The historical and documentary evidence shows that a large number of expeditions for the purpose of securing slaves were made during this period. By the year 1474 in the Spanish city of Seville the slaves were so numerous that Ferdinand and Isabella nominated a celebrated Negro, Juan de Valladolid, as Mayoral of Negroes in that city.

With the accession of John to the throne of Portugal in 1481 the traffic in African slaves became a regular, though somewhat restricted, trade, for in that year the Portuguese established a fort on the Gold Coast and commenced the regular shipment of slaves. Forts were also established along the coast of West Africa as far south as Angola near the mouth of the Congo River, the first slaves actually being drawn from the vicinity of the Senegal, Nunez, Benin, and Congo Rivers. By 1539 from 10,000 to 12,000 Negroes were being sold annually, for domestic purposes, in the great slave market at Lisbon. A large proportion of these Negroes were very probably absorbed by miscegenation in the Portuguese population, in much the same manner as occurred later in other countries. However this may be, by 1502 we find evidences of Negroes already well established in the New World chiefly on the island of Hispaniola (the island on which is situated the Republic of Haiti, and Santo Domingo), where they were for the most part employed in the mines. The precise date of the introduction of Negroes into Hispaniola cannot be fixed, but it was probably some time between 1495 and 1500. These Negroes were imported from Spain and were Christians. But with the increased demand for laborers the sale of licenses for the import of "bozel" Negroes (or those direct from Africa) was initiated by Ferdinand in 1513. That year may well be taken to mark the commencement of the Afro-American slave trade.

Without having attempted any highly documented history of slaving in Africa and Europe, we may none the less say with some degree of security (1) that slavery as an established institution over a wide area of Africa was known and practiced long before the appearance of the white man and (2) that in Europe itself the trade in African Negroes as slaves was practiced, in Portugal and Spain, for at least fifty years before the discovery of the New World. Thus, by the time that the importation of African Negroes as slaves into the New World began, the slavery pattern had already long been established among the Negroes themselves as a practice, if not as an institution, with which they were familiar.

Among the discoveries of the New World the trade in slaves for the purposes of domestic labor, not to mention the commercial

profit, had but relatively recently become a strongly established and increasingly vigorous pattern of behavior. With the discovery of the New World the stage was therefore set. Firstly, there were in Africa millions of human beings who were aware of slaving and slavery as a custom which was to some extent practiced among all the tribes with which they were familiar, and who took it for granted that it was not only possible but even desirable to raid or make war against other tribes for the purpose of securing slaves. So that when the Europeans arrived in search of slaves they soon found that it was not war that they had to make in order to secure them, but "gifts"—to the Kings, Queens, and Chiefs who were more than ready to supply the demand of the European "traders." Secondly, the impetus given to the demand for slave labor by the discovery of the New World came at a time when slave-trading had but recently assumed an organized form as a branch of legitimate commerce and was—almost as if it had been timed—ready for the boom in human flesh.

These two patterns of conditions serve to explain both the ease and the rapidity with which the slave trade grew. The fact that the African Negroes had been traded as slaves to Europe for some fifty years before the discovery of the New World serves to explain the readiness with which the Europeans unhesitatingly accepted the suggestion, as soon as it was made, that the labor of Negro slaves was the solution to the first, and most immediate, economic problem of the New World.

African Origins of the American Negro

For the purposes of this discussion the present limits of the United States will be taken as equivalent to what we shall understand by "America." By Africa we shall mean the whole of that continent in all directions of the compass.

As Herskovits has pointed out, two approaches are possible to the solution of the problem of the African origin of the American Negro, the one historical and the other ethnological.

The historical approach must rely principally upon documentary sources relating to the slave trade, and secondarily upon the recorded observations of travelers.

The ethnological approach relies upon the investigation of African culture traits among American Negroes and the tracing of them to their counterparts in Africa. It is obvious that the ethnological approach forms, at least, a partial check upon the historical method.

We shall deal first with the historical evidence, and finally with the ethnological evidence.

Historical. Hispaniola, the island of Santo Domingo which today contains the republic of Haiti, was discovered by Columbus in 1492. There is an unconfirmed tradition that Columbus brought two Negroes with him from Spain on his first voyage of discovery. Since Columbus experienced great difficulty in recruiting a crew, and since Negro slaves were abundant in the port of Palos from which he sailed, this is not unlikely. It is not certain when Negroes were first introduced into Hispaniola, but they must have been introduced very shortly after the second voyage in 1493, for a decade later, in 1502, we find Ovando, governor of Hispaniola, petitioning "that no Negro slaves should be sent to Hispaniola, for they fled amongst the Indians and taught them bad customs, and never could be captured."

By the year 1520, four thousand Negro slaves were being imported annually into all the islands of the Greater Antilles (Cuba, Jamaica, Hispaniola, and Puerto Rico).

When Negroes were first introduced into continental America is not absolutely certain. The date is generally given as 1619 when, as John Rolfe tells in his *General Historie* of John Smith, "about the last of August came in a Dutch man-of-Warre, that sold us twenty negars." This date seems surprisingly late, and will hardly appear credible to those who still labor under the impression that Columbus discovered North America. The fact is that the *mainland* of North America was first seen by John Cabot, in 1497, but no attempt at colonization was made by Europeans until 1562 when the French Huguenots established a colony at a site near the present town of Beaufort in South Carolina, and another, in 1565, in Florida. These colonies were soon ruined. In 1586 Sir Walter Raleigh made unsuccessful attempts to settle a colony of English in

Virginia at Roanoke in what is now North Carolina. It was not until 1607 that the first lasting settlement was made in Virginia by the English, but it was apparently not until twelve years after the settlement of this colony that the first Negro slaves were introduced, in 1619, into North America. From 1569 to 1618 England's only connection with the slave trade was a thoroughly indirect and casual one, coming through the occasional capture of prizes carrying slaves. In the light of this fact, and the fact that the Virginia colony was at the time twelve years old, it may be taken as reasonably certain that Negroes were first introduced into North America in the year 1619. If any Negroes were in existence in the colony before that date, they must have been very few indeed. Thus, the first Negroes to land in America did so exactly one hundred and twenty-seven years after Columbus discovered the West Indies and South America. During this period of time, the West Indies and Brazil had been steadily receiving increasing supplies of Negro slaves; at first, for a short period, Christian slaves from Spain, and simultaneously, and soon exclusively, "pagans" from Africa.

It may be that the Negroes landed from the "Dutch man-of-Warre" in Virginia in 1619 were part of a prize taken by the Dutch somewhere in the West Indies, but for this there is no evidence, as there is none for the origin of these Negroes. On the other hand, it must be pointed out that from the year 1611 on the Dutch had established themselves as slave-traders on the Gold Coast and the Gambia. It therefore seems most probable that the first Negroes to arrive in North America were imported by the Dutch from the Gold Coast, possibly from Mouree, where their first fort, Fort Nassau, was built in 1612. To the Gambia the Dutch had acquired access in 1617, so that it is also possible that our Negroes came from this region of West Africa. By the middle of the seventeenth century the Dutch had substantially displaced the Portuguese hold of almost two centuries upon that coast. The Dutch thereafter carried on their activities from the Gambia to Angola, leaving the Portuguese to the Cape Verde and Gum Coast.

It is desirable to point out here that during the two centuries of Portuguese domination of the Gold Coast much intermixture occurred between the natives and the Portuguese, and it is said that this left a considerable impress upon the physical characteristics of the natives themselves; so that it is possible that some of the Negroes who came to America had some Portuguese ancestry.

After the sale by the Dutch of the first Negroes to arrive on these shores, the rate at which they were thereafter purchased is unknown. As early as 1630, eleven years after the importation of the first Negroes, the Virginia colony found it necessary to provide for the public confession and whipping of a white man-servant for "defiling his body in lying with a Negro."

The period during which Negroes were imported as slaves into America lasted some 240 years, from 1619 to 1860.

The Portuguese, Dutch, British, and French slavers all traded from the coast of West Africa, and between the islands of the West Indies.

As we have seen there is a general belief that the African Negro was brought to North America from almost every part of Africa. Herskovits has strongly combatted this view, pointing out that both the historical and ethnological evidence agree in giving the American Negro a practically exclusive West African origin. A survey of the available evidence indicates that Herskovits is substantially correct in his judgment that the vast majority of the slaves who reached this country came from West Africa. Certainly, slavery in Africa was a continent-wide practice, but Herskovits points out, "Slaves captured in the interior of West Africa or in the eastern part of the continent were much more likely to be taken to the native states of North Africa, to Egypt, or to Arabia than to be brought by way of the dangerous route overland to the West Coast and the slave-ships or to be transported by sea on the long journey around the Cape of Good Hope."

It is probable, nevertheless, that some slaves did reach the coast of West Africa from the interior, but if that was so we have no evidence either as to their numbers or their provenience. It must be remembered that the coast of West Africa, from the Senegal to Angola, extends for a distance of some 4,000 miles. There is good reason to believe that the density of the populations occupy-

ing the coastal regions of this area was quite sufficient to supply the many millions of souls who were shipped from every part of this vast territory to the New World. All the names of native places and tribes mentioned in the existing documents of the trading companies are of West African coastal or near-coastal provenance. Similarly, Ollendorps, a German missionary who was sent out to the Virgin Islands as an inspector of missions, and published a report in 1777, found that the tribal origins of the slaves could all be traced to peoples inhabiting the region from the Gambia River to the mouth of the Niger.

Ethnological. With respect to the ethnological evidence it may be said that this, in every way, confirms the above conclusion. Place names, tribal names, customs, language, and music gathered among the Negroes in the New World all point in the same direction, namely, to West Africa.

We conclude, then, that the available historical evidence indicates that the Negroes who were shipped as slaves from Africa to North America were taken from the peoples whose original homes extended all the way from Senegal in the north to Angola in the south along the West Coast of Africa.

Extra-African Origins of the American Negro

Under this heading we shall briefly inquire into the origins of these African Negroes who found their way to North America indirectly from Africa. Such an inquiry is, of course, of fundamental importance for an understanding of the ethnic composition of the American Negro. Some interesting facts will be seen to emerge.

We have already seen that Negroes were first brought to Europe during the conquest of Spain by the Moors in the latter part of the twelfth century of our era, and that up to the discovery of the New World at the end of the fifteenth century Negroes were steadily being imported into Spain. These Negroes came chiefly from North Africa, and some from the East Coast, and Madagascar. Those from North Africa appear to have come chiefly from the region of the Sudan in the northeast. From the northwest Rio di Oro, the Great Desert regions, Libya and the regions further south, the Arab slave routes led towards Morocco, whence the slaves were sold to all the Moslem states, to Asia Minor and Turkey, to Spain, and to Portugal. Essentially the same regions were later to be exploited by the Portuguese, chiefly for the Brazilian market.

In Spain and Portugal much mixture must have occurred between Negroes drawn from very different parts of Africa, as also between the Moors, the Spaniards and the Portuguese. We shall be justified in regarding the Negro population of Spain and Portugal at the end of the fifteenth century as an already much mixed one. The point is important because the Negroes who were first sent out to the New World were drawn from Spain and later from Portugal.

The number of Negroes who were exported to the New World from Spain and Portugal is unknown. A large number of them, as we know, were Christianized, but we find early references to some who were not, "pagans," and interestingly enough, Berbers—in Hispaniola in 1506. Since such mixed Negroes were later exported to most of the islands of the West Indies and to Brazil, and since some of these mixed individuals later found their way to the mainland of North America, however slight their contribution may have been to the ethnic composition of the American Negro, it is a point which must be kept in mind in any discussion of that composition.

With the discovery of the New World intermixture between the Negroes and the indigenes of the West Indies began almost at once. Thus, as we have already seen, in 1502 we find the newly arrived Ovando, governor of Hispaniola, petitioning the Spanish Court "that no Negro slaves should be sent to Hispaniola, for they fled amongst the Indians and taught them bad customs, and never could be captured." With the increase in the demand for slaves, Negroes were soon being shipped directly from Africa to the West Indies and Brazil, and it is here that the evidence becomes clear that, as far as the West Indies are concerned, very large numbers of Negroes reached these islands who came from parts of Africa which were not restricted to the coastal regions of the western part of that continent.

In addition to the West Coast, the Portuguese are known to have exported slaves to

the West Indies and to Brazil from East Africa, particularly Mozambique.

From the Upper Congo above Stanley Pool, from the Central Niger region, from Hausaland, and from the lower Congo, towards what is now Northern Rhodesia, slaves were drawn in great, but indeterminate numbers. Slaves from these regions were being shipped to the Americas as late as the second quarter of the nineteenth century and, according to Torday, even later.

While it seems clear that many Negroes were brought to the Americas from places in Africa besides the West Coast, it should be equally clear that, owing to the considerably greater remoteness of these parts from the Americas, appreciably fewer Negroes can have been brought from them than were brought from the West African coast.

Thus, again we must conclude that the majority of the Negroes who reached the New World were predominantly of West African origin, but that there were also appreciable numbers among them who were derived from North-Central, South-Western and East Africa. It must be supposed that these Negroes were already very thoroughly mixed, among themselves and with the Indians of the islands and of the mainland of Brazil, by the time most of them reached North America.

It is known that many of the slaves imported into the English colonies came by way of the West Indies, and unquestionably some of these were of mixed blood. The mingling of Negroes and Indians, of course, occurred first in the West Indies. Interestingly enough, there seems to have been an appreciable amount of inter-island trading in Indians and Negroes, and lots of the one were occasionally exchanged for the other. Thus, for example, Indians and Negroes were simultaneously introduced into the Bermudas for the first time in 1616, the supply being continued through importation of Negroes from Africa and "redskins," the latter sometimes in exchange for Negroes. Many of the colored people of Bermuda are said to show in their physiognomy the influence of the Indian type.

Ethnic Mixture of the American Negro

From the very beginning the American colonies held Indian and Negro slaves. The principal effects of the relation between Negroes and Indians as fellow slaves has been summed up by Reuter:

> Slavery of the native Indians existed in a number of English colonies before the coming of the Negroes. Those captured in battle were in some cases sold into slavery in distant colonies. Others were kidnapped along the coast and sold as slaves in the more settled regions. . . . With these enslaved Indians the Negro slaves came into close and intimate contact. The social status was the same and as slaves they met on terms of equality. Intermarriage following and, as the body of Negro slaves increased and Indian slavery declined, the Indian slaves were gradually absorbed into the larger black population.

One of the most interesting results of Indian-Negro contacts was the development of a regular slave-trade among certain Indian tribes. Thus, for example, the civilized tribes in the Indian Territory did an appreciable trade in Negro slaves. A government investigator in 1841 and 1842 reported that "Comanches steal Negroes sometimes from Texas and sell them to Cherokees and Creeks. The latter have been known to pay $400 and $500 for a Negro."

The available evidence indicates that mixture between Indians and Negroes has been of vastly greater proportions than has hitherto been realized.

At least two Indian tribes, the Creeks of Georgia and an offshoot of the latter, the Seminoles of Florida, were completely Africanized. The Seminoles, or "runaways," treated their Negro slaves virtually as equals; and in the Seminole wars the Indians and Negroes fought side by side.

Negro-Indian mixture has occurred, to a greater or lesser extent, throughout America. Such intermixture has proceeded down to the present day wherever Negroes and Indians have come into contact. In recent years there has been some mixture between Negroes and Mexican Indian peons brought into the sugarbeet plantations in Kansas.

Negroes look upon Indian ancestry as something of which to be proud. Thus, 27.3 percent of the Negroes—out of a total of 1,551 individuals—examined by Herskovits claimed some Indian ancestry. At the present time, however, no significant admixture of Negro and Indian stocks is in progress.

Negro-White Mixture

Until the publication of Herskovits's classical studies the enormous extent of Negro-

white admixture was hardly realized even in the best informed quarters. At the present time it is still impossible to make any definite statement as to the number of Negroes in America who have some white ancestry, and the number of whites who have one or more Negro ancestors. Census returns are of little value here owing to the arbitrary methods of classifying Negroes, Mulattoes, and whites. All that it is at present possible to say is that it is probable that the majority of Negroes have some white ancestry. According to the 1920 census some 20.9 percent of the Negro population consists of Mulattoes. Writing as an anthropologist with genetical interests, the present writer would put that figure nearer 80 percent if we take the term Mulatto to refer to the presence of some white ancestry in an individual of primarily Negro origin. This figure of approximately 80 percent is confirmed by Herskovits's finding on a representative sample of 1,551 Negroes.

The Negroes have from the earliest days mixed with all classes of the white population, the mixture for the most part being between Negro women and white men.

During the Colonial period, when white women were scarce, Negro women naturally received a great deal of sexual attention from the pioneer whites. During the period of slavery, the slave owners and their sons frequently made free of such Negro women as took their fancy. Thus, there was a good deal of mixture between "upper class" whites and Negro slavewomen. Up to the present time the polygynous relationship in which a white married man maintains a colored woman, and his children by her, persists in many parts of the United States.

Actually, our knowledge of the relative frequencies with which members of the different classes among whites are responsible for miscegenation is quite unknown, but it is a safe inference that all classes of the white population are involved.

Negroid individuals from other parts of the New World have not entered America in very large numbers, but such as have entered have certainly been quickly absorbed in the American Negro population, and there can be little doubt that in certain localities, particularly on the eastern seaboard, they have helped to modify somewhat the physical type of the Negro. That modification, however, has always been towards the Negro side of the balance rather than otherwise. But this is a matter upon which evidence is conspicuously lacking.

That the Negro population every year loses some of its members by "passing" of those who may "pass" for whites is certain, and although the number who do so is unknown, the proportion who are thus lost is probably negligible. "Passing" has little, if any, effect upon the physical character of the white population since an individual who passes from the Negro to the white group must genetically be considered white. The birth-rate of the Negro population so far exceeds the death-rate that such losses by passing can be considered to play no significant role in limiting the size of the Negro population. The physical character of the Negro population is, however, definitely affected by passing, for the "passers" were potential lighteners of skin color, and in that sense they represent a definite loss to the Negro population which, on the whole, prefers lighter skin colors to the darker ones. Since dark men tend to marry lighter women, it seems clear that the Negro population is destined to become stabilized around a skin color which is definitely "black" or dark-brown, though somewhat lighter, on the average, than that of the true West African Negro.

The Ethnic Composition of the Negro Population Today

The American Negro population of today is a composite of African, white, and Indian elements. The American Negro is often described as a *hybrid*. But a hybrid is the offspring of two distinct lines, and the American Negro is rarely, if ever, that. He is, on the other hand, the end-product of many lines. He is, firstly, a much mixed African who has, secondly, been much mixed with a large variety of whites—Spanish, Portuguese, Dutch, British, and French—and, thirdly, there has been a considerable addition to this admixture in the form of the New World and American Indian. The American Negro population, we may say with Herskovits,

> combines the traits of its ancestral racial types, and has so blended them that any given feature is about

equidistant between the typical African feature, on the one hand, and the typical European and American Indian features, on the other. We can therefore say . . . that the American Negro resembles all of his ancestral types, and yet is none of them. He is distinctive among human beings. Varied though American Negroes may seem to our untrained eyes, when we actually test the extent of this variation, we find that it is no greater than that found among any of the so-called "pure races" from which they have come.

Reproductive Differentials and Probable Future of the Negro

Census figures show that the Negro population has increased from 757,208 in 1790 to 11,891,143 in 1930. The percentage of Negroes in relation to the total population in 1790 was 19.3, whereas in 1930 that percentage was only 9.7.

This difference is, of course, not due to a decline in the relative fertility of the Negro, but reflects rather the disproportionately greater increase of immigrant whites into this country as compared with the comparatively insignificant immigration of Negroids. Since immigration of whites is now much restricted we may expect a relatively marked increase in the numbers of the Negro population. Recent studies of the Negro population problem show that the Negro is now reproducing at a more rapid rate than the white. In 1930 the birth-rate of Negroes in the Registration area was 21.6 per thousand population compared with 18.7 for whites. The birth-rate of Negroes per thousand enumerated females in the reproductive ages, 15 to 45 years, was 82.5 and that of whites 78.4. The average number of children born to mothers who had been delivered of a child in 1930 was 3.6 for Negroes and 3.1 for whites.

The Negro death-rate is everywhere in America higher than that of the whites. Thus in 1930 the death-rate per 100 persons was for Urban Negroes 22.8 as compared with 12.0 for whites, and for Rural Negroes 17.0 as compared with 9.5 for whites. Infant mortality is about 60 percent higher than that of whites. For the same year the total Negro death-rate was 16.92 as compared with 10.91 for the whites.

As all investigators are agreed, the high Negro death-rate merely reflects the poor health conditions under which Negroes are for the most part forced to live. The mortality has been chiefly due to preventable diseases, and as soon as something is done to improve the health services and the conditions of life under which the Negro population struggles for existence, there can be little doubt that both the Negro and the white mortality rates will very appreciably decline.

The reproductive tendency of Southern Mulatto families has been slightly higher than that of black families living in the same localities.

The better socio-economic status of the Mulatto must here, on the whole, be held accountable for his superior reproductive tendency.

The prediction of population changes is at best a hazardous affair. Too many variables are involved, and it is quite impossible to predict the future history of all these variables with any degree of certainty. On the basis of certain assumptions, however, which have been made by Whelpton, a relatively greater increase is predicted for the Negro population between 1930 and 1980, when Negro females may increase by more than 49 percent and white females at little less than 36 percent. All students of this subject agree that a relatively greater increase of the Negro population is something which can be predicted with certainty, having regard to the observable trends in the variables concerned and of the Negro population itself. For the next hundred years, at any rate, it may be confidently predicted that the color of the Negro population will tend towards a more uniform distribution of the darker shades, so that we may expect a larger Negro population more uniformly dark-brown colored, or "black," than the present Negro population of America.

POPULATION PROBLEMS OF A NEW WORLD ORDER

By KARL SAX

PROMISES of an abundant life and freedom from want for all peoples of all nations seem to be made with no consideration of agricultural production or population pressure. The universe may be expanding, but this world is not, and already many parts of the world cannot support the existing populations at much more than a subsistence level. Man lived and multiplied on this earth for five hundred centuries before the population reached 850,000,000 people, but at the end of one additional century the world population had doubled. During the recent past the world population has been increasing at the rate of one percent a year, a rate which would nearly double the present population before the end of this century.[1] There are now forty persons per square mile of land area in the world. The population density of the United States is almost exactly that of the world as a whole. Some parts of the world have high population densities; other areas are sparsely populated. In some areas the populations are growing rapidly, while in other regions the population is at a stationary level. It is the differential population growth and density in various parts of the world that present difficult problems in establishing global unity so essential to world peace and security.

I

It is estimated by competent authorities that about two and one-half acres of arable land are needed to provide a human being with essential food, clothing, and other necessities.[2] The total area of all crop land in the world is about four billion acres, according to Dr. H. H. Bennett, head of the United States Soil Conservation Service. The world population is now over two billion, so that the cultivated land per capita is only two acres. There is more land that can be cultivated in many parts of the world, but most of it can be farmed only with diminishing returns or at a much greater cost of production. Many regions of the world are already overpopulated on the basis of domestic agricultural production. With the exception of Russia, practically all the nations of Europe and Asia are no longer able to produce enough food to maintain adequate nutritional standards. The population of large parts of Asia manages to live on less than one acre of arable land per capita, but the masses do little more than survive and many do not even do that very long. Millions of acres have been exhausted by continued cultivation and erosion, and no new acres are available in these densely populated areas. The answer to the population problems of Europe and Asia would seem to be the proper distribution of either the populations or the food supplies of the world, but in practice this solution is not at all simple.

When population pressure exceeds the food supply, as it does in many parts of the world, there are several paths of escape. The overcrowded nations of Europe have followed three methods. Industrialization and modern methods of transportation have enabled these nations to maintain populations whose food requirements exceed their own agricultural production by importing food in exchange for manufactured products. Population pressure also has been relieved by the migrations of the people of Europe to the new nations of the Americas, Australia, and Africa. These two methods are possible only when other parts of the world can still support larger populations or can produce a surplus of food products. The third method followed by the peoples of Europe, in spite of legal and religious bans and the exhortations of priests and politicians, is the artificial reduction of the birth rate. Most of the European countries have reduced their birth rates during the past fifty years from over thirty per thousand to less than twenty per thousand. In fact, many of these countries —England, Germany, France, Austria, and

[1] R. Pearl, *Natural History of Population*, 1939.

[2] P. E. Brown, "Land and Land Use," *Science*, 83: 337–343, 1936.

the Scandinavian nations—have had birth rates below replacement levels, and nearly all the others are rapidly approaching a stationary or diminishing level of population. Of the countries of Europe, only the Slavic nations have anything approaching the "natural" birth rate of forty per thousand, and only Russia has agricultural resources to support a much larger population. As the socio-economic conditions improve in Russia, her birth rate too will decline.

Population pressure in Asia is even greater than it is in Europe, but the nations of Asia have found no satisfactory solution. More than half of the world population lives in Asia, with little relief from population pressure by migration, industrialization, or birth control. Only Japan has developed industries sufficient to permit her to import a considerable part of her food supply. Industrialization and aggression have enabled Japan to double her population during the past fifty years, but the increase is maintained only by low standards of living and long working hours. China and India have birth rates considerably higher than Japan's thirty per thousand, but their populations have grown more slowly, because these countries have been unable to provide for a rapidly growing population. The Malthusian law operates with little restraint in continental Asia. Population has increased faster than food supply and has been held in check only by famine, pestilence, and natural catastrophes.

Can the people of Asia meet the problems of population pressure? What are the prospects of increased food supply, migration to sparsely populated regions of the world, or reducing birth rates to the level of agricultural production?

Food production in Asia cannot be increased appreciably. Most of the agricultural land already is in cultivation and, owing to intensive cultivation, produces more per acre than our farm land. The farms are small, averaging two and seven-tenths acres in Japan, three and three-tenths acres in China, and a little more in India. Three-fourths of the population derives a living from agriculture.[3] Modern agricultural methods would result in little increased production, although they would release many people for the development of essential industries.

Industrialization of Asia can increase the food supply only so long as other nations are able to produce a surplus of agricultural products. The leading food exporting countries are Russia, Argentina, Canada, and Australia. Russia, with her resources and modern methods of farming can export large quantities of food after the war, but if her birth rate remains at forty per thousand, Russia will, in another generation, require all the food she can grow. Improved socio-economic conditions in Russia probably will reduce the birth rate, but this will be offset by higher living standards. Argentina is able to export a third of the food she produces, and Canada one-fifth. Europe alone will require most of the exports of both Australia and Canada. These and other food exporting countries can supply a considerable agricultural surplus for some years, but most of them are growing rapidly and will have little surplus food for export in another generation.

Emigration offers little hope for Asia, because most of the other regions of the world are already populated or controlled by the white races. It seems improbable that Australia, Canada, the United States, and the countries of South America will welcome large numbers of Asiatics with any greater enthusiasm in the future than they have in the past. Most of these nations will acquire their own optimum populations in a relatively short time, without the questionable benefits of Asiatic immigration. Certainly there is no moral reason why those nations which restrain their birth rates to improve their standards of living should provide for the surplus populations of other countries which breed without consideration of the economic and social consequences.

Invasion of neighboring countries, already overpopulated, provides no more *Lebensraum* for the invader unless the peoples of the conquered nation are exterminated. Such a practice cannot be tolerated in a civilized world. Nor is there any biological justification for the myth of racial superiority, which has been used by the Nazis as an

[3] G. B. Cressey, "Agricultural Regions of Asia," *Econ. Geogr.*, 10: 109–142, 1934.

excuse for their attempts to enslave or exterminate neighboring peoples and racial elements of their own population.

Let us assume that we can help feed and industrialize Asia and increase the standard of living. So long as birth rates of forty to fifty per thousand persist, the population will increase just as fast as food supplies and medical science will permit. The only rational solution of population pressure in Asia is the reduction of the birth rate. But among both nations and individuals the practice of birth control tends to be limited to the more fortunate socio-economic groups. The social and economic conditions in Asia would seem to preclude any general practice of birth control, unless recent advances in contraceptive methods make birth control more generally available and practicable than is now the case.

II

Many misguided optimists believe that there will always be enough for all regardless of the number of people who occupy the earth. Such optimism is not limited to newspaper columnists, such as Dorothy Thompson, who assures us that there is "enough for all" in this world of modern science. J. D. Bernal, a reputable English scientist, suggests that if we could convert coal and limestone into food materials "we should have enough food for a population thousands or millions of times that which exists at present."[4] An increase of one thousand times would establish a population density of 40,000 persons per square mile of land surface of the world, while an increase of a million times would mean that there would be less than one square foot of land area available for each person! Nor is Bernal's faith in agricultural science shared by those who know something about the subject. It is true that England can support one person per acre of cultivated land, but it can be done only by intensive cultivation, liberal use of fertilizer, an exceptionally favorable climate, and a low standard of living for a large part of the population. Her agricultural index of productivity is one hundred and seventy-seven compared with the world average of one hundred, but this does not mean that the rest of the world can reach England's level of productivity.

It is true that science has made almost incredible contributions in the field of communication, transportation, production, and labor-saving machinery. Scientists will continue to work miracles for the benefit of mankind, but it is improbable that they can do much to increase agricultural production. During the past fifty years, plant breeding, crop rotation, the use of fertilizers, pest and disease control, and the use of modern agricultural machinery have increased yields per acre by as much as forty to sixty percent in the United States. This is a remarkable increase, but it has been almost completely offset by the deterioration of the natural soil fertility and by new problems in pest and disease control. According to the U. S. Department of Agriculture Yearbook for 1938, we are little more than maintaining crop yields at a stationary level in spite of remarkable advances in agricultural science. The same trend is true in other countries. Some nations have higher yields per acre than we do, but largely because of more intensive cultivation and less production per man. The American farmer cultivates an average of twenty acres; in Belgium one man cultivates only five acres; and in China the average area cultivated per man, or woman, is less than one acre.[5] One-fifth of our population can produce sufficient essential food with a surplus for the "ever normal granary," but in China three-fourths of the workers are engaged in farming and produce only enough food for minimum needs, with little or no surplus for lean years. Whenever a large proportion of the population is required to produce the food supply, the standard of living for all is maintained at low levels. We could produce more food by more intensive cultivation and by using more submarginal land, but this could be done only by lowering the living standards of the entire population.

Since the world population density is approximately that of the United States, a further examination of our population and our resources is of particular interest. The United States is well endowed with natural

[4] J. D. Bernal, *The Social Function of Science*, 1939.

[5] E. M. East, *Mankind at the Crossroads*, 1926.

resources for a high degree of industrialization and has large areas of fertile land for agricultural production, but in normal times we just about balance food imports with food exports and ship to foreign countries only about ten percent of our American-grown food. We can produce more food but not enough to feed many more people either here or abroad. According to the U. S. Department of Agriculture Yearbook, the present crop land area is somewhat more than four hundred million acres, but of this area about sixty percent is subject to erosion under current agricultural practices, or is too poor to farm at a profit. Half of this land subject to erosion or too poor to farm profitably should be retired from cultivation. Of the land not now in cultivation, less than fifty million acres should be used. Thus if we include all crop land of any value which can be maintained in cultivation, the total is about three hundred and seventy million acres or less than three acres per person. At present, we use over three acres of arable land per person, and still we do not provide adequate food for a large part of our population. According to the Food Nutrition Board of the National Research Council, our pre-war diet was deficient by the following amounts: fresh vegetables fifty-nine percent; milk forty-five percent; citrus fruits and tomatoes twenty-eight percent; beans, peas, and nuts twenty-five percent; eggs seventeen percent and meat, poultry, and fish only four percent. Cereals were adequate, and there was an excess of fats and sugar. The deficiency of protective foods is largely a problem of economics, but these foods are expensive to produce and distribute.

There may be a temporary solution of the food problem, without relying on the chemists to produce food from air, sawdust, and coal. Our normal diet consists of about forty percent animal products—meat, eggs, milk, and cheese. It requires six to eight times as much land to produce food in the form of meat and milk as it does to produce the basic cereal and legume crops. The reduction of animal products in our diet would release more of the basic food crops for human consumption. Recent work done at the Massachusetts Institute of Technology seems to show that the basic cereals and legumes, fortified with essential minerals and necessary vitamins, can provide an adequate diet without meat and milk or even without fresh vegetables and fruit. Such a diet would be as satisfactory as that enjoyed by the European peasant or the Asiatic coolie, although it might be more monotonous. In normal times this basic diet should be supplemented with the usual foods we enjoy, but in an emergency it would provide more food for more people.

Actually there is little need for the Occidental peoples to look forward to synthetic food supplies or a cereal diet. Their growth rate is becoming adjusted to agricultural resources, and with few exceptions those countries with limited resources have reached a stationary or diminishing population. Recent trends in the United States indicate that our population will be stabilized at about one hundred and sixty million. It is only in the Asiatic countries that population pressure is likely to exceed any possible increase in food production. Is the Occidental world going to adopt Oriental standards of living in order to feed and industrialize the peoples of Asia? It seems premature to speak of raising the standards of living for all races, when even the richest Occidental nations are unable to provide a reasonable standard of living for a large part of their own populations. During the past year the exportation of only six percent of our food supplies to our allies and increased consumption of food by our war workers and soldiers have led to a food shortage in spite of the fact that we had bumper crops in 1942.

III

The decline in birth rates in the western world has done much to reduce population pressure, but it has raised other problems which threaten the internal security of these nations. The threat which disturbs political and religious leaders is the fear that their nation or their sect will be submerged by more rapidly breeding nations or religious groups. France is often cited as the horrible example of the consequences of birth control. France has long had an approximately stationary population, but in the years before the present war France had a higher stabilized rate of natural increase in population

than did Germany, England or the Scandinavian countries. If all the countries of Europe had reduced their birth rates when France did, there would have been little excuse for more *Lebensraum*. If manpower were the determining factor in war, a population race between France and Germany would mean the defeat of France, simply because Germany has resources to support a larger population, just as Russia is destined to control all of Europe if she so desires. In a peaceful world there would be no need for expansion of population to the limits of subsistence, and each nation could maintain an optimum population level in accord with adequate living standards for all. Even in a world at war, a large population does not necessarily imply military might. China has at least five times as many people as Japan.

In all countries in which the practice of birth control is prevalent, the differential birth rate between the different economic and educational classes is a matter of considerable concern. The situation in the United States is typical of most Occidental nations. According to Lorimer *et al.*, in *Foundation of American Population Policy*, the urban white families with annual incomes of over $3,000 had a reproductive index of only 0.46, while those with earned incomes of $1,000 a year or less had about twice as many children. But the only class which exceeded replacement levels in 1935 were those on relief, with a reproductive index of 1.43. Does this trend indicate that we are approaching the conditions of a termite society in which a specific caste is maintained only for the purposes of reproduction? Even in normal times the third of our parents least able economically to raise and educate children produces two-thirds of our future generation. The same trend is found in relation to education. College graduates have relatively few children as indicated by their reproductive index of 0.57, but those with less than a seventh grade education have had a reproductive index of 1.18. Fortunately our rural population has a considerably higher birth rate than our urban groups.

The dependence upon the poorer and more ignorant members of society for the major portion of our future generation is not conducive to the best development of the individual or the nation. If poverty and ignorance are the result of bad heredity, the excessive fertility of this group will result in the lowering of the average capacity of the population. If, on the other hand, the more unfortunate members of society are the result of poor environmental conditions, the consequences are equally serious because such parents cannot provide a favorable environment for their children. Actually both heredity and environment are responsible for individual development. Man is subject to the laws of heredity in both physical and mental development, but the relation between inherent ability and success is so obscured by environment that it is difficult to determine an individual's innate mental capacity. The mental defectives belong to a special category, and there is no question about their undesirability for parenthood.

Why do those who are least able to feed, clothe, and educate children have much higher birth rates than the more able, or more fortunate, members of society? The late Dr. Raymond Pearl, of Johns Hopkins University, has provided the answer based upon a survey of more than 30,000 women in urban maternity hospitals in the United States. Differences in birth rates among the various racial, economic, educational, and religious groups are due almost entirely to differences in the prevalence and effectiveness of the practice of artificial contraception, and to a minor degree to differences in age of marriage and the practice of criminal abortion. Among the rich and well-to-do, eighty-three percent of the mothers with more than one child practiced contraception, while among the very poor classes only thirty-five percent used, or attempted to use, contraceptive methods. Pearl's detailed records show that these poor mothers had large families due primarily to ignorance of contraceptive methods and to irresponsibility, rather than to a desire for many children. This conclusion is supported by a survey made by the *Ladies' Home Journal*, in which it was found that practically all married couples want children and that nearly all want more than one, but that relatively few want more than four.

The greatest enigma of this age of science

is the present status of the knowledge and practice of contraception. Public opinion surveys made by the Institute of Public Opinion and by the *Ladies' Home Journal* show that more than three-fourths of the people of this country approve of the dissemination of birth-control information by the medical profession and even of government-supported birth-control clinics. Dr. Pearl's data show that the majority of married women practice, or think they are practicing, some form of artificial contraception.[6] Yet our archaic laws prevent the dissemination of reliable information and keep the $250,000,000 contraceptive industry on a semi-bootleg status.[7] This seems particularly inexplicable in view of the fact that religion is no longer an important factor in suppressing such information. Nearly all the Protestant churches approve of artificially controlled birth rates, and in 1930 Pope Pius gave at least implied approval of "natural" birth control.[8] Although the Catholic Church still opposes artificial contraception, it is practiced by Catholics to about the same extent as it is by Protestants of similar economic and educational status.

Both nations and families are confronted with the same problems. If they have more children than they can feed and educate, they are doomed to lower living standards and higher death rates and are handicapped in economic and cultural development. But if they do curtail birth rates they are in danger of being overrun by the unrestricted breeding of their neighbors. The logical solution would seem to be the control of birth rates in accord with the national or family resources. At the same time, every effort should be made to insure equal opportunity for all. Only with equality of opportunity can the inherent capacities of all individuals be fully developed.

The history of both empires and families seems to show that a relatively high degree of culture and economic success tends to be followed by degeneration or extinction, just as in evolutionary history those species which developed a high degree of specialization often failed to survive, while more degenerate or more aggressive species survived and flourished. Evolution does not guarantee progress, but only change. Man has been able to control his environment to a remarkable degree, and there is no reason why he should not be able to control his social evolution. But it cannot be done by abandoning rational thought and reverting to mysticism. We need more of the scientific method, particularly in the field of social relations and human conduct.

The control of the birth rate is an established feature of Occidental civilization, and it must be adopted by the Oriental nations if the problems of population pressure are to be solved. The world cannot remain half slave and half free in control of population growth. There is not enough for all in many parts of the world, and unrestricted population growth in these areas can lead only to aggression or to chaos. Unrestricted birth rates not only are a threat to world security, but also they involve the freedom of the individual. This freedom must be extended to all classes and to all races if there is to be equal opportunity for all.

[6] Less than five percent of the contraceptors use methods recommended by most birth control clinics.

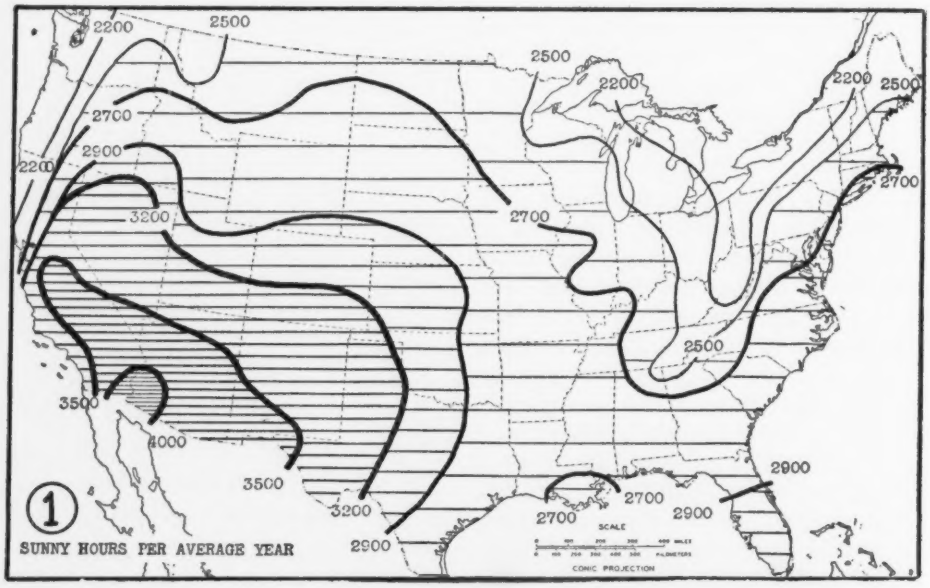
[7] "The Accident of Birth," *Fortune*, 17: 83–86, February, 1938.

[8] In Boston we are still told that "birth control is against God's Law."

SUNSHINE AND CLOUDINESS IN THE UNITED STATES

By STEPHEN S. VISHER

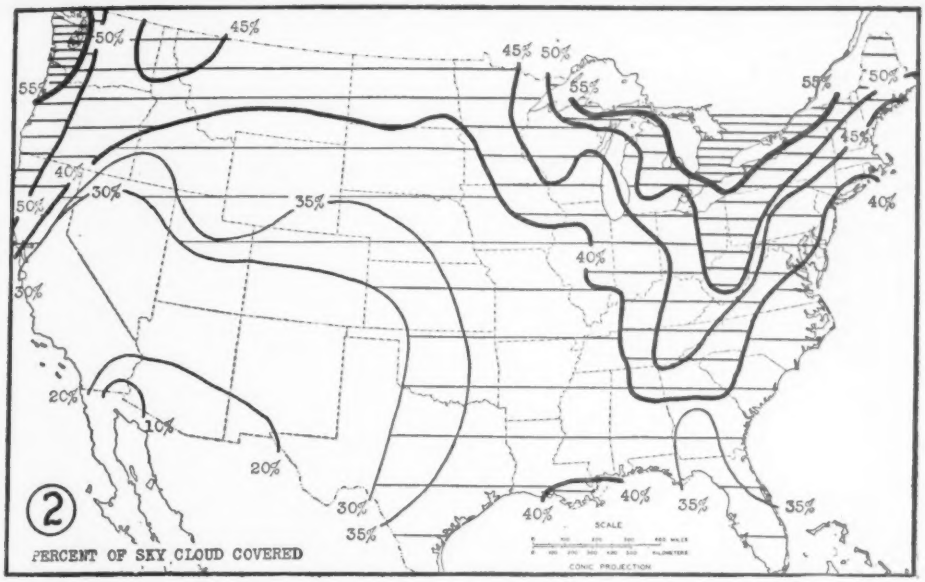
SUNSHINE is a climatic factor of diverse and profound significance, for it sharply affects the amount of heat received by the surface of the earth from the sun. Sunshine is also an increasingly recognized health-giving influence. In parts of the world where sunshine is inadequate, at least for a part of the year, human health is adversely affected. This is especially true of children who fail to develop properly in cloudy areas unless the natural sunshine is supplemented by "bottled sunshine" (fish liver oils) or ultraviolet light. Bright sunshine, however, may be harmful to various animals, especially insects, and to many delicate plants, and sometimes to man.



MAP 1. AVERAGE NUMBER OF HOURS OF SUNSHINE PER YEAR

The amount of cloudiness strongly affects the temperature by night as well as by day. In all seasons, cloudy days are generally cooler than clear ones, but cloudy nights are distinctly warmer than clear ones. This is because the clouds serve as a blanket. The amount of cloudiness also affects the beauty of the sky. For example, stars on clear nights make the sky beautiful, and scattered clouds add to the beauty of a moonlit night. Clouds add greatly to the beauty of dawn and sunrise, and of sunset and evening. Grey, overcast skies, on the other hand, reduce all the colors of nature and have a depressing effect upon most persons. Studies by Ellsworth Huntington indicate, nevertheless, that although most people prefer bright weather following a cloudy period they usually accomplish less work on a clear day than on a partly cloudy one. A long succession of clear days has a depressing effect, as is evident from the sense of relief commonly felt when clouds return, as for example in southern California after the almost cloudless summer.

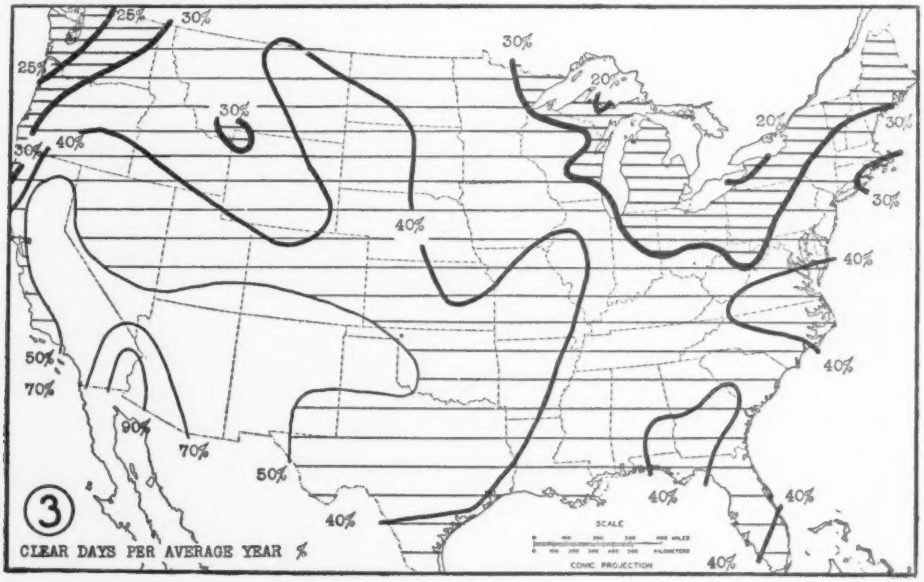
Within the United States there are notable regional differences, and also sharp seasonal contrasts, in the amount of sunshine received. The accompanying maps, based on official Weather Bureau data gathered at the approx-



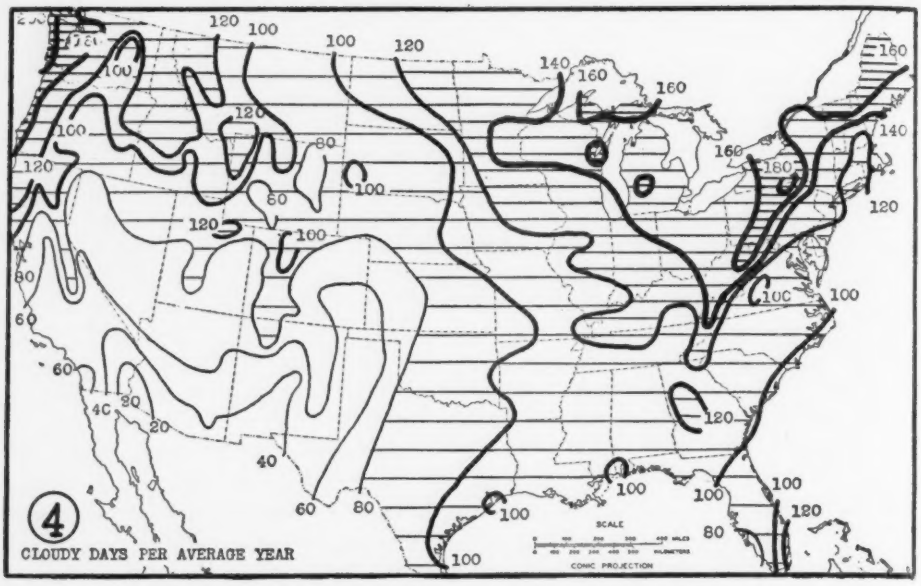
MAP 2. AVERAGE PERCENTAGE OF SKY CLOUD–COVERED BY DAY

imately two hundred first order stations, present various aspects of widespread interest.

Map 1, of the annual average number of sunny hours, shows that the Pacific Northwest and a part of the Northeast receive on the average less than 2,200 hours of sunshine a year, or an annual average of less than six hours per day. Southern Florida and a large southwestern region receive, however, more than 2,900 hours a year, which means an average of more than eight hours a day. A considerable southwestern area receives ten hours a day, on the average. This map shows a general decline northward in the amount of sunshine received per year. Exceptions occur, however, in areas near the Pacific Coast and near the Great Lakes, both of which receive considerably less sunshine



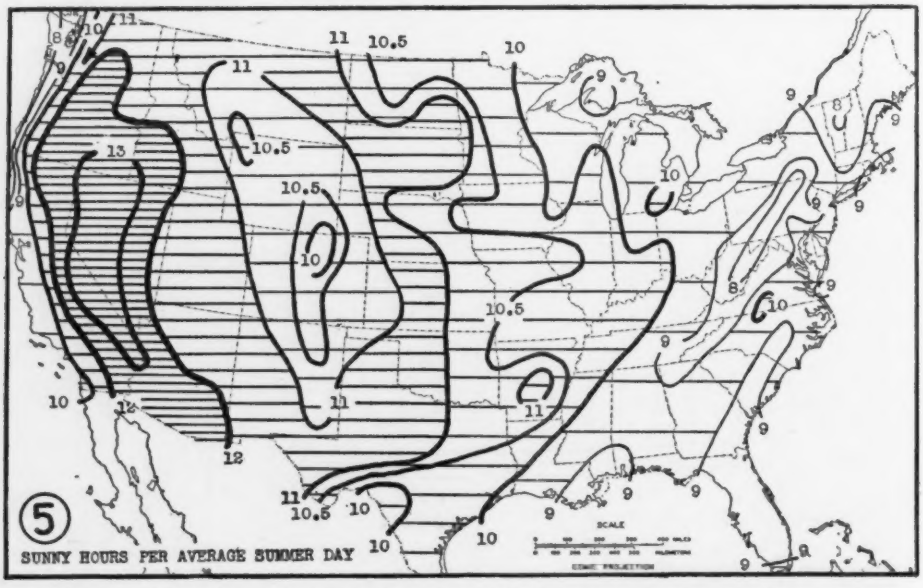
MAP 3. AVERAGE PERCENTAGE OF CLOUDLESS DAYS PER YEAR



MAP 4. AVERAGE NUMBER OF CLOUDY DAYS PER YEAR

than similar latitudes nearby. The southern Appalachian Mountains also are relatively cloudy, as is implied by their popular name, "The Great Smokies." The greater sunshine in the Southwest than in the Southeast is due, of course, to its aridity. Map 1 is original, based on all the records of the first order stations to 1931.

Map 2 shows the average percentage per year of the sky which is cloud-covered by day. It will be noted that along the northern Pacific coast and in a large northeastern region, the sky is half cloud-covered on the average. In Florida it is cloud-covered more than a third of the day time, but in a large southwestern region it is cloud-covered less than one fourth of the day time. This original map is based on the difference between



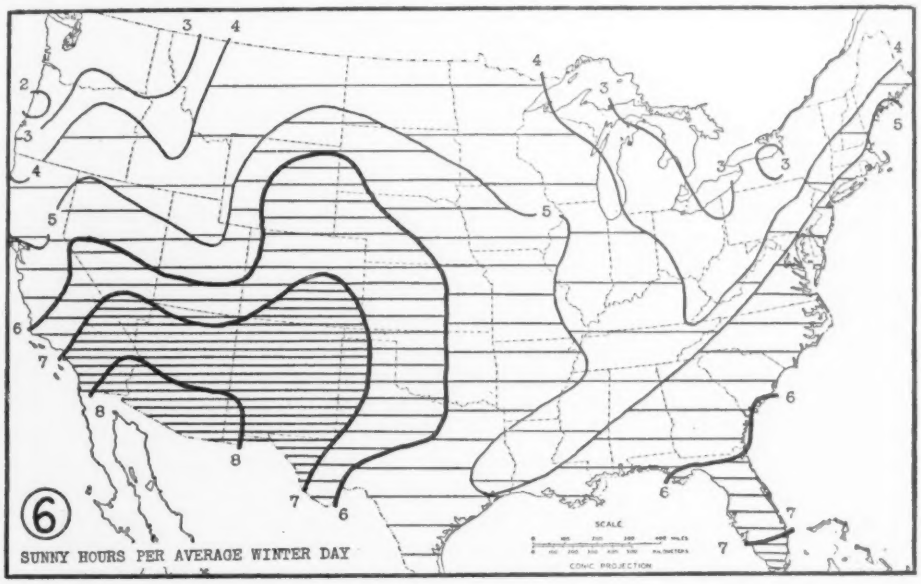
MAP 5. AVERAGE NUMBER OF HOURS OF SUNSHINE PER SUMMER DAY

one hundred percent and the published "annual percentage of possible sunshine."

Clear days (map 3) are twice as frequent in the Southwest as in the Northeast or Northwest. Indeed, in the Imperial Valley near the mouth of the Colorado River, more than nine-tenths of the days are clear, while parts of the shores of the Great Lakes have less than one-fourth of their days clear. This map is a shaded copy of one by Kincer in the *Monthly Weather Review* for 1920.

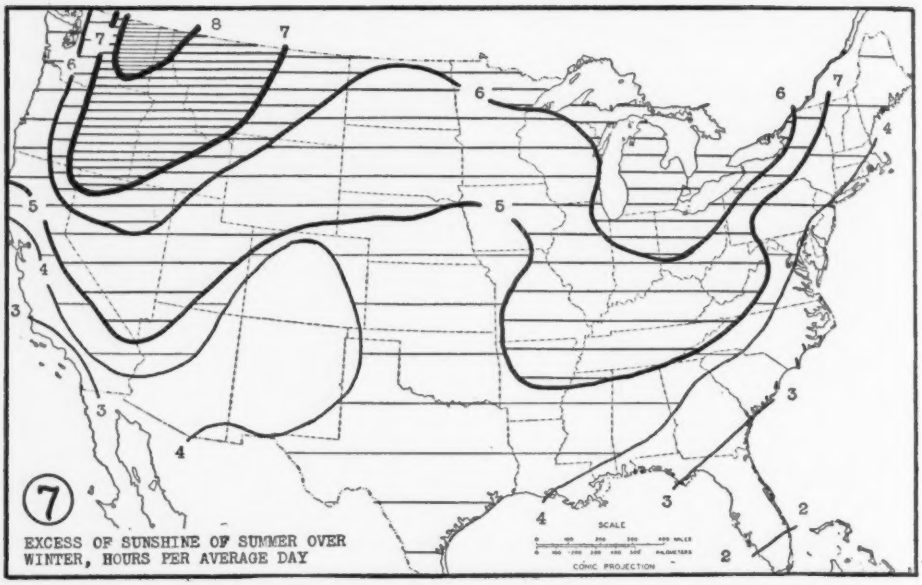
Cloudy days (map 4) occur only rarely in southern Arizona where Yuma has fewer than twenty per year. Moreover, on most of those that are cloudy the sun is seen either at sunrise or at sunset. To emphasize this fact, the Yuma hotel advertises that it does not charge its guests for board or room on any day that the sun does not shine. It very seldom fails to charge. In sharp contrast to southern Arizona, several areas bordering the Great Lakes have on the average more than one hundred and sixty cloudy days a year, while in western Washington the number of cloudy days is greater than two hundred per year. This map is a redrawing of one in the 1941 Yearbook of the Department of Agriculture, *Climate and Man.* (The Yearbook maps were made under the direction of J. B. Kincer.)

Seasonal contrasts in sunshine are shown in maps 5–7, 5 and 6 of which are redrawn from those in the 1941 Yearbook. Map 5 shows that in summer the eastern third of the country receives on the average less than ten hours of sunshine a day. The northern half of that eastern third receives fully as much as the southern half, partly because in the North the days in summer average more than an hour longer than in the South. The cloudiest eastern regions are in the Appalachians and northern New England, partly because of greater convection in mountainous areas. On the Pacific Coast there are, on the average, three or four fewer hours of sunshine per summer day than there are a short distance inland from the coast, much of this difference being due to fog. The Great Plains are notably less cloudy in summer than the East or the Rockies, proving that the author of "Home on the Range" was correct in his observation that there "the skies are not cloudy all day."



MAP 6. AVERAGE NUMBER OF HOURS OF SUNSHINE PER WINTER DAY

Map 6 shows that in winter the Great Lakes region and adjacent areas to the east and southeast receive less than four hours of sunshine during an average day, while the North Pacific coast receives only two to three hours a day. Florida is notably sunny in winter as compared with much of the North-



MAP 7. AVERAGE EXCESS IN HOURS OF SUNSHINE OF SUMMER OVER WINTER

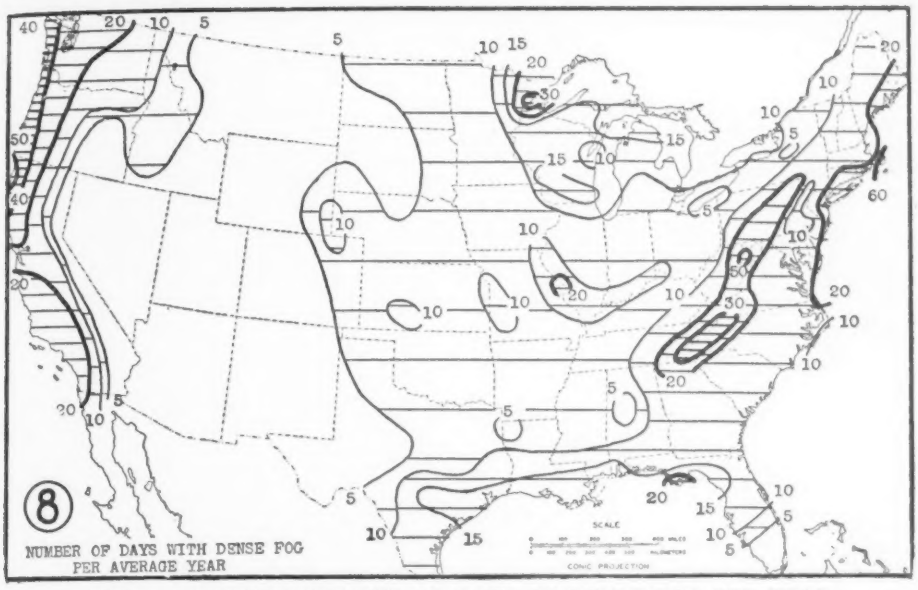
east, but the sunniest region is the Southwest, with an average of 7 to 8.5 hours of sunshine per day.

Map 7 shows the difference between the daily hours of summer and winter sunshine. This original map reveals that in Florida a summer day receives on the average only from two to three more hours of sunshine than a winter day but that near the Great Lakes the average for the summer is about six hours more than for the winter. Residents of the Great Lakes Region naturally appreciate Florida's sunshine in winter, but in summer they have about as much at home. The greatest regional contrast is seen in eastern Washington, where the winter is very cloudy while the summer is almost as sunny as it is in southern Arizona.

The final map, 8, shows the average number of days per year of dense fog (based on the map in the 1941 Yearbook). It is seen that along the Pacific Coast twenty to fifty days have dense fog, but that in a broad western belt and in southern Florida fewer than five days a year have fog. The foggiest part of the East is Cape Cod, averaging more than sixty foggy days a year, but part of the Appalachians are almost as foggy.

The influence of the Great Lakes on the amount of fog is interesting. The area to the south and southeast of the Great Lakes has little fog, although it has relatively little winter sunshine (map 6). Fogginess is greatest for this general region, according to this map, to the west of Lake Michigan and Lake Superior. Another interesting detail shown is the greater fogginess along the lower Ohio River Valley and the Mississippi River Valley above the mouth of the Ohio. The Ozarks and the Black Hills also have evident influences, just as do the Appalachians, but effects of western mountain ranges are not evident. This suggests that the larger western valleys, in which most of the western Weather Bureau stations are situated, normally are too dry for fog. However, various lesser valleys at high elevations have much fog.

Several influences conspicuously affect the distribution of sunshine and cloudiness. Increased distance from the equator affects the length of day and the average temperature. In the north the relatively long summer days give more hours of summer sunshine but, conversely, their shorter winter days mean relatively fewer sunny hours. As the capacity of air for moisture is doubled or halved with each change of eighteen degrees Fahrenheit in temperature, the higher average temperature of the South makes for more sunshine than in the North because of greater vaporization of the atmospheric moisture.



MAP 8. AVERAGE NUMBER OF DAYS OF DENSE FOG PER YEAR

As average temperatures decline sharply with increased altitude, there is a corresponding rapid decline in capacity for moisture, resulting in a general increase in cloudiness and fog in mountainous areas. Mountain cloudiness is also increased by convection. As the ocean and the Great Lakes are relatively warm in winter as compared with the nearby land, cloudiness and fog are greater over and near them, on the average, than inland. As cloudiness is a form of moisture, it declines on the average, with reduction in availability of moisture. Hence, between the ocean and the mountains there is more cloudiness than on the lee side of the mountains. This helps explain the relatively lesser cloudiness in the West. Much cloudiness is caused by convectional disturbances, the most conspicuous example of which is the thunderstorm. Hence, where there is sufficient moisture and air disturbance to yield thunderstorms, cloudiness is increased. As the relative coolness of the Great Lakes in summer interferes with the development of local convection and often weakens approaching thunderstorms, this condition helps make the lake region relatively sunnier in summer. Thus, although the lakes increase cloudiness during the cooler months, they reduce it in hot weather.

Although data on cloudiness at night is inadequate, it is known that the drier parts of the country which are relatively sunny by day are even more generally clear at night. This is because where the air is dry, escape of heat from the earth is rapid as the sun goes down. As a result, the local convectional currents which are required to keep the clouds suspended, die away. Then gravity draws the cloud particles down to warmer air levels where they evaporate. Very often in all parts of the country the clouds clear away as night approaches. This is least common in the humid regions where dew formation liberates much latent heat and thus retards the cooling of the lower air. It is most common where there is relatively little moisture in the lower air.

Another contrast in cloudiness not shown by these maps is in the density of the cloud cover. In the drier regions the clouds are often thin while in the cloudier East and Pacific coastal areas clouds are often so thick as to be "leaden." Indeed, in these cloudier regions many thinly clouded days are recorded as clear by the Weather Bureau's sensitive photographic instruments, which continue to operate. However, on such days high thin cloud may cut out a considerable fraction of the ultraviolet light.

SCIENCE ON THE MARCH

FOR some time to come "Science on the March" will be the experimental section of *The Scientific Monthly;* that is, we will experiment with it as to form and contents. We have a definite objective for "Science on the March"; we wish to show a panorama of the advancing fronts of science in such a way that a scientist on one front may get an idea of the action on other fronts and anyone interested may get a bird's eye view of the whole. If we could sit, like Zeus on Olympus, and see and understand all the diverse activities of science, we could approach our objective immediately; but we are subject to human limitations and also to restrictions imposed by the war on the dissemination of scientific information. So at present we shall have to present a peep-show instead of a panorama. The more information we get from the officers at the various fronts about the progress of their units, the more nearly shall we be able to present the desired panorama.—EDS.

FOOD

Throughout the world the great problem now is how to grow more food with less labor and materials. This involves related problems on the kinds of food that should be produced so as to get the greatest nutritive value with the least expenditure of time and effort. Then come the problems of food protection, preservation, and distribution.

Research on food problems must now be devoted largely to answering pressing questions, utilizing so far as possible the results of previous research and doing only the kind of experimental work that tells us "what" and "how," but not "why." For example, the study of the conversion of solar energy into food by the green plant must coast while we find out how to serve soy beans to replace meat. Practical short-term research on food thrives under organization and cooperation among different specialists: chemists, agronomists, plant pathologists, entomologists, engineers, and so on. Thus we find the United States Department of Agriculture bringing together under the new Agricultural Research Administration most of the research bureaus of the Department, so that during the war period the broad practical problems can be more readily recognized and different specialists can be brought together to solve them. It is to be hoped that the more individualistic, long-term research problems will not be forgotten and will be given free rein after the war.

Corn. One way to get more food without increase in labor is to grow plants or raise animals that are inherently more productive of foodstuffs than those previously employed, or to grow a higher percentage of the better yielding varieties than was done before. For example, by growing hybrid corn, which nearly always outyields the open-pollinated varieties, six bushels of corn may be obtained where five were produced before. According to the Department of Agriculture, the practice of planting hybrid corn has expanded tremendously during the war. It is estimated that in the year 1942 about 630 million bushels of corn represented the bonus from the use of hybrid seed. Present research must deal with the problems of production of hybrid seed. What combinations of parent corn give the best seed for particular areas?

But that is not all. If disease or insects should take a large proportion of the crop, it will have been to no avail to have used an inherently high-yielding hybrid. Hybrids differ in their susceptibility to disease and insect attack. So the corn breeders work with plant pathologists and entomologists to develop hybrids that not only have the desired agronomic characteristics but also are highly resistant to the pests that might attack them. In northwestern Ohio, where the European corn borer has been prevalent, it would no longer be possible to grow corn commercially, if borer-resistant hybrids had not been developed. With the spread of the borer westward, Indiana and Illinois must revise their corn hybrids to meet the threat of this pest from Europe.

After corn is grown and harvested it must be stored for a time. In the granaries, weevils may attack it. To keep these pests under control it is necessary to gas the insects.

This is done by pouring or sprinkling upon the surface of the grain a volatile liquid which will trickle down among the kernels, evaporate, and pervade the whole mass with vapor toxic to the insects. The important ingredient of one new mixture is the same substance that is used for delousing soldiers' clothing. Another promising liquid makes the eyes water, but it reaches the bugs. Still another is a liquid that is used primarily in the production of one of the synthetic rubbers.

Milk. What is true of corn is in part true of cows. It is desirable to increase milk production because milk is a protective food which in many areas can be produced more efficiently than meat. We can get more milk without having more cows by replacing low producers with high producers. As the science of plant breeding leads to a greater yield of corn, so the science of animal breeding can increase milk production. According to the Department of Agriculture the average production of the dairy cows of the United States is 4,700 pounds of milk per year. The more select cows of the Dairy Herd Improvement Associations yield almost twice as much on the average. Thus the possibility of great improvement in the general average of milk production is obvious. Research in animal breeding has shown that it can be brought about by the use of proved bulls for propagation of dairy herds. The inheritance of a good bull can be greatly extended by the use of artificial insemination.

Reports on some aspects of the British attack on the problem of milk production, described below, are condensed from a summary by Professor John Hammond, F.R.S., physiologist of the Animal Nutrition Institute, University of Cambridge, and Fellow of Downing College.

The marked variation in seasonal production of milk in England has made it necessary to limit its consumption to an average of two pints per week per person during the late autumn and winter months. This seasonal shortage occurs because in winter many heifers and young cows do not go through the physiological cycle necessary for becoming pregnant. Injections of stilboestrol, a synthetic sex hormone, was suggested as a remedy but it proved to be ineffective.

On the other hand, injections of preparations of horse anterior pituitary gland or pregnant mare serum hormone (P.M.S.) have been shown to be very effective. Since supplies of these substances came mainly from France, Denmark, and Holland, steps had to be taken to obtain local supplies.

Large numbers of small wild ponies, in which the concentration of P.M.S. hormone is higher than in larger horses, were available in Wales and the New Forest in Hampshire, but, as the dates of service were unknown, an accurate method of determining the stage of pregnancy was required. The method of rectal palpation of the uterus was satisfactory, and supplies of serum were collected and prepared for use.

The effects of P.M.S. hormone on a cow depended on the stage of the physiological cycle of the animal at the times of the injection. When an injection of P.M.S. hormone was made in early or mid-cycle, no ovulation occurred. If an injection was made towards the end of the cycle, several follicles ripened and all ovulated together. By adjusting the time and dose, twin and triplet calves have been obtained, but the frequency of sterile female calves (freemartins) and males, which are not wanted by the dairy industry, is thereby increased. For the beef industry, however, it would be desirable to get as many sound offspring per cow as possible. Therefore injection of P.M.S. hormone may become commercial practice in England when the supply of feeding-stuffs for beef cattle again becomes normal.

Somewhat similar results have been obtained with sheep, but goats, however, can be caused to become pregnant outside of the normal mating period by one injection of P.M.S. hormone. Such injections have been found useful to increase the winter milk supply. Maiden goats can be brought into milk within the space of a few weeks by treatment with a cheap synthetic sex hormone, such as stilboestrol.

F.L.C.

SYNTHETIC SEX HORMONES

Substances that influence the reproductive cycle in animals are known as sex hormones or oestrogens. According to John Harley-Mason of Cambridge University, England,

they are secreted by the anterior lobe of the pituitary gland (gonadotrophic hormones) and by the sex glands themselves. Male sex glands secrete testosterone and oestrone, and female glands produce oestradiol.

The gonadotrophic hormones are, as it were, the prime movers; passing from the pituitary into the bloodstream, they cause the gonads to produce their respective secretions. If these hormones and the hormones of the sex glands could be made in the laboratory, the way would be cleared for treatment of reproductive disorders in man and animals, and for modification of the reproductive cycle of animals to suit the needs of man. Much chemical research has been done in England and other countries on the determination of the molecular structure of natural sex hormones and on the building of identical or similar synthetic molecules. The structures of the gonadotrophic hormones are still unknown, but those of some of the sex gland hormones are now understood and oestrone has been synthesized.

Since the synthesis of sex gland hormones is a matter of great difficulty, two British organic chemists have been working on syntheses of compounds that have some similarity to the known structure of the female hormone, oestradiol, hoping to produce some substances that will have the same physiological effect as oestradiol and at the same time will be commercially feasible to produce.

Injecting their synthetic compounds into female mice and observing whether proliferation of the cells lining the vagina occurred, they found that one compound, which is called stilboestrol, had almost the same effect as the natural oestradiol. Stilboestrol, the full chemical name of which is 4:4′ dihydroxydiethylstilbene, can be quite readily synthesized in five stages from easily available materials.

Application of stilboestrol for increasing milk production in goats was noted above. This compound and a similar one, called hexoestrol, are now widely used clinically in sexual disorders of women and, according to Harley-Mason, have proved highly successful.

A derivative of stilboestrol, known as diethylstilboestrol, also originated in England. According to the United States National Cancer Institute, diethylstilboestrol may be useful for treatment of cancer of the prostate gland. Since experiments so far made with it have not always cured the disease nor even given temporary relief from pain and other symptoms, it would be premature to say that diethylstilboestrol is the answer to this problem.

F.L.C.

THE JOHNS HOPKINS UNIVERSITY SCHOOL OF MEDICINE

Science marches on many fronts—in the study or the laboratory of the recluse, in the shelter of university halls, in the industrial laboratory, in the association of scholars as a school, an institute or a foundation. Medical science in America has never marched with higher purposes or greater strides than at The Johns Hopkins University School of Medicine, which has recently celebrated the fiftieth anniversary of its founding.

The Johns Hopkins University opened its doors to students of the arts and sciences in 1876, and the doors to the School of Medicine, in 1893. In the establishment of the university, and of the school of medicine as well, a new note was struck in American education and medical science. The whole institution was dedicated to research and scholarship on the highest possible plane; it was a place where the most promising young scientists would work under the most eminent scholars. The standards set by this institution during the first twenty years of its existence transformed the ideals for graduate schools in American universities.

The Johns Hopkins University School of Medicine was not the result of an inspiration speedily executed. It was contemplated from the opening of the University in 1876; the first definite steps toward the organization of a medical faculty were taken by President Daniel C. Gilman in 1884, and the University Hospital was opened in 1889, but the School of Medicine was not formally opened until six years later. In this long interval a department of chemistry was established under Ira Remsen; William H. Howell was appointed Professor of Biology; and William H. Welch, Professor of Pathology, began to organize broad courses in bacteriology, pathology and related fields. Preparatory to

opening the School of Medicine in 1893, Dr. Welch gathered around him such men as William T. Councilman, Franklin P. Mall, Simon Flexner, William Osler, Howard A. Kelly, and John J. Abel and recalled William H. Howell from Harvard. These are great names in American Science. Councilman, Mall, Flexner, Abel, and Howell were members of the National Academy of Sciences; Welch was its president during 1913–1917. Welch, Flexner, and Abel were elected to the presidency of the American Association for the Advancement of Science.

For the first time in American medical education all professors conducting preclinical courses were devoting their "entire time and strength," to use President Gilman's words, to their work as scientists. In other institutions courses in medicine were given almost entirely by practicing physicians. The new methods were later extended to the major clinical departments. This innovation at The Johns Hopkins University School of Medicine spread until it revolutionized medical education in this country. As early as 1902, only seven years after the School of Medicine opened its doors to students, Charles W. Eliot, President of Harvard University, speaking at ceremonies on the retirement of President Gilman, said:

> The twenty-five years just past are the most extraordinary twenty-five years in the whole history of our race. Nothing is done as it was done twenty-five years ago; the whole social and industrial organization of our country has changed, but among all the changes there is none greater than that wrought in the development of medical teaching and research; and these men whom you, sir, summoned here have led the way. . . . Among the achievements of Johns Hopkins University in the last twenty-five years, let this improvement of medical teaching be counted as one of superb beneficence.

Measured by dry statistics, The Johns Hopkins University School of Medicine has given the degree of Doctor of Medicine to 2,918 men and 361 women. This is indeed a considerable army of medical men and women, but they have not been an army of privates keeping weary steps to beating drums. On the whole they have been high officers, moved by more varied and richer tones, who have led the medical forces of a continent to unexpected heights. The effects of the wisdom and the pursuit of the high ideals of Gilman and Welch and their many associates today reach directly and indirectly not only throughout our land but into all of our far-flung battlefronts.

F.R.M.

ROACHES

The prevalent method for wiping out an infestation of German roaches is to distribute a powdered insecticide in or near the cracks in rooms inhabited by these pests. A suitable powder properly applied will exterminate the insects in a few days, but powder deposits are untidy. Moreover, one of the preferred ingredients is temporarily difficult to obtain and the other is thought to be a menace to health when used in kitchens where the little dark-brown roaches are most numerous.

A neater and safer, but slower, method of roach control, was recently demonstrated by the inventor. For his demonstration he chose an infested kitchen. He filled ordinary test tubes with a weak solution of boric acid in water, plugged the tubes with absorbent wads, and distributed them inconspicuously in the kitchen. In about three days dead roaches were seen on the floor and at intervals for several days thereafter bodies of additional casualties were swept up until the kitchen was practically roach free. In principle: the roaches must drink water; unable to distinguish boric acid solution from tap water, they imbibe the former freely from the wet plugs of the test tubes. And so they meet an unnatural but timely end.

C. S. BARNHART

BOOK REVIEWS

MAN AND SOCIETY[1]

THE book consists, as explained in the subtitle, of "observations and reflections on man's nature, development and destiny." Its contents are presented in three parts, the first of which deals with the human species, its subdivisions and evolution; the second with individual development and heredity; and the third with a general philosophic discourse on a multitude of subjects which lie close to the heart of anyone who ever wondered about man and society. The book is written in a smooth, readable style and is apparently intended for the average non-scientific reader.

Professor Conklin is well known to many sections of the reading public. His scientific work in embryology occupies an important place in the development of American science, and his long career as professor at Princeton University has earned for him a worthy niche in the teaching of science. Aside from this, Professor Conklin has performed valuable service as president of the American Philosophical Society and has been useful in inspiring many scientists with respect for and even interest in social and philosophical problems, an inspiration badly needed in an age which extolled technical specialization and regarded with suspicion all concern with cultural and philosophical questions.

And yet, in spite of the author's record, the book is far from being satisfactory and suffers from many defects common to the efforts of many biologists who venture to write on the subject of what man is. To begin with, biologists seldom pay adequate tribute to anthropological findings. Stressing as they do the biological aspects of *Homo sapiens,* they emerge with biological material which is very interesting but hardly relevant to man's uniqueness. Few scientists who have devoted much thought and research to this question can fail to reach the conclusion that the distinctly human aspects of man can be described far more stimulatingly and soundly by anthropological data of culture patterns, their origin, diversity, spread, and disappearance, than by a study of embryology or even genetics. Yet few biologists have shown awareness of this point and most continue to talk of man in terms of the zoological sciences.

As a result of such oversight, when philosophically minded writers on biology come to discuss, as does Professor Conklin in the latter part of this volume, the question of human values, religion, the role of tradition, humanitarianism, militarism, racism, or escapism, all they have to offer is personal judgments eked out of subjectivity and possessing no roots in evidence even of a controversial nature. To add to the futility of such intellectual ruminations, the discussions are usually repetitions of what has been heard hundreds of times before and contain no new stimulation or challenge.

Most of the philosophical problems raised in *Man, Real and Ideal* are stale. One may venture to say that few of them will seem new to any reader, regardless of how average he may be and how interested he may be in reading books with a title such as this one. Even the subject of the meaning of religion to man is handled with a timidity which is reminiscent of the last decades of the nineteenth century when people who arrogated to themselves the label of the vanguard of progress declared faith to be the "opium of the people." Surely anthropology and the history of science and ideas in our own culture have much to say on this subject and reach different conclusions. The evidence for or against the validity of this slogan, inscribed on the walls of the Red Square in Moscow in the early days of enthusiasm, can be weighed in the light of historic and social data requiring no apologies or hedging.

Even from a strictly biological angle it is possible to write a general book on man and bring out some salient scientific problems which are relevant to our understanding of the subject and which stimulate the mind. Yet from this point of view as well, *Man, Real and Ideal* can hardly be considered suc-

[1] *Man, Real and Ideal.* Edwin Grant Conklin. 264 pp. 1943. $2.50. Charles Scribner's Sons.

cessful. The mystery of development which it presents sketchily is not sufficiently linked to human conduct to make it stimulating. The physiology of sensation, a far greater and more basic mystery so far as human behavior is concerned, is untouched. Evolution is discussed, but in terms of orthodox natural selection without taking cognizance of the major difficulties it is still confronted by and the newer experiments and ideas bearing on its limitations and possibilities.

As a result of these omissions, the book makes for smooth but superficial reading. It is difficult to see how the reader can carry away even one stirring thought on the subject of man which would make him feel that he has learned anything. One cannot disagree with Professor Conklin's ideas, his social values, or judgments. The book radiates a humanitarian and democratic social philosophy, a broadmindedness often lacking in such subjective accounts. Consequently there are no jarring and impassioned falsehoods, no perversions of truth because of fanaticism or over-enthusiasm. But these virtues are not sufficient to cover its inadequacy in substance.

MARK GRAUBARD

BIOLOGY OF THE ITCH MITE*

THIS is a timely volume on the itch mite of man, by an author who has contributed much to our knowledge of this obnoxious parasite. Beginning with a consideration of the mites in general, the author then reviews the very early literature on the itch mite, starting with the seventeenth century. In so doing he gives reproductions of many figures published by the early workers, some of which are very quaint, even fantastic.

In the latter part of the volume the reader finds an extended treatment of our modern knowledge of the biology and anatomy of this mite, which, surprisingly, is referred to as *Acarus scabiei*. This is done notwithstanding the fact that in opinion 113, of the International Commission on Zoological Nomenclature, the time honored generic name of *Sarcoptes* was declared the proper one for *scabiei*.

Studies of the biology of the different forms of *Sarcoptes* have revealed a very interesting picture from the standpoint of taxonomy and evolution. All the forms of *Sarcoptes* which occur on man and domestic animals are anatomically so nearly alike that the slight differences between them, if and when present, are almost completely concealed by individual variations. Yet each of these forms is to a certain degree specific in its host relationship. The situation is very similar to that of geographical raciation, where the morphological differentiation is but slightly indicated. Possibly the term "host raciation" could be applied with propriety to it. The method of attack of the itch mite of man is very different from that of any other mite which attacks him in that the female tunnels under the surface of the skin. This is in sharp contrast to the method of attack by chiggers. They do not penetrate the skin but attach themselves to it by means of their chelicerae, in the manner of a tick.

Although no bibliography accompanies the text of this book, many footnote references are given to the literature cited.

H. E. EWING

* *Biology of Acarus Scabiei.* Reuben Friedman. Illustrated. 183 pp. 1943. $3.00. Froben Press.

MICROBIOLOGY FOR NURSES*

WITH the creation of the United States Cadet Nurse Corps by Congress near the close of the last session it is only natural to find a marked increase in the number of textbooks in the field of nursing: new books and revised editions. This textbook belongs under the latter designation, being the third edition of a book enjoying a rather wide adoption.

The material covered is divided into two parts: first, the general principles of infection, resistance, and disinfection; second, microorganisms of medical importance. In the preface the author indicates certain features which have been retained or introduced for a specific purpose. One of these is the practice of indicating in the body of the text the derivation of technical terms. This is of undoubted help to the student, although it is well known that the derivation of a word does not necessarily convey its present meaning. An extension of this treatment to the

* *Microbiology. A Textbook for Nurses.* Royall M. Calder. Third Edition. Illustrated. 317 pp. $2.50. 1943. W. B. Saunders Company.

terms of pathology as well as those of microbiology would be of further use, bearing in mind that in most instances the students have just finished high school.

The discussion of the hypersensitive state, including anaphylaxis and serum sickness, in the chapter "Mechanisms of Bacterial Pathogenicity" is distinctly out of place but, unfortunately, this topic is nowhere given adequate attention. The nonspecific defensive mechanisms of the body are very briefly treated. Surely inflammation should be considered among them, together with the activity of the fixed phagocytes of the tissues. Phagocytosis is taken up only as an introduction to the descriptions of the opsonins. In the discussion of the antigen-antibody complex and its application to skin tests, the general statement that "whenever antigen and antibody come into contact with each other in the presence of living body cells, damage is done," is immediately contradicted by the explanation of the Schick and Dick tests. The chapters on the destruction of bacteria are clear and well planned. The discussion of the use of steam under pressure, however, is inadequate. The erroneous impression that "15 pounds pressure for fifteen minutes" are sufficient for sterilization can hardly be avoided. Under "intermittent heating," no mention is made of the fact that the materials being treated must be able to support growth if spores are to develop into vegetative cells during incubation. The author's insistence on the use of tincture of iodine, and not alcohol alone, for skin disinfection, and of cresol for the disinfection of thermometers is to be highly commended.

The common and important pathogens have been included in the second part of the book. In each chapter, the special nursing problems incident to the disease in question are listed. The segregation of the venereal diseases in a separate chapter is open to some question. If this is done, to be consistent the respiratory as well as other types of disease should be classified similarly. The discussion of food poisoning seems out of place in the chapter on Clostridia.

There are a number of errors in the book, of which the following will suffice as an example. Surgical removal of the infected gall bladder never "sterilizes" the intestinal tract. Better integration of clinical and pathological findings with bacteriological data would prevent the impression given on page 215 that laboratory tests constitute the final diagnosis of such diseases as syphilis.

The book is exceptionally well printed, well bound and of a convenient size.

MALCOLM H. SOULE

ANIMALS OF THE ROCKIES*

A busy twenty-two years among the large game of the Western United States gives a forest ranger, who liked his job and did it, background for a most engaging book.

The author took every advantage of his opportunities to observe these creatures and he knows how to tell about them. In thirty-five chapters the reader meets personally bears, comic and terrible; elk, single and in herds; deer, antelope, mountain sheep and goats.

He encounters bankers and buffaloes, catches poachers, doctors sick wild deer, finds a lost herd of thousands of antelope.

This is a spendid book, replete with intimate facts about the animals and told in a manner that makes one want to keep on reading.

The photographs taken by the author are a fitting accompaniment to the tales.

WILLIAM MANN

* *Wild Animals of the Rockies—Adventures of a Forest Ranger.* William Marshall Rush. Illustrated. ix + 296 pp. 1942. Harper & Brothers.

PLATES AND FILMS
for
Spectrum Analysis

The Eastman Kodak Company makes a number of plates and films which are suited to the various requirements of spectrum analysis. One of the most recent of these products is *Eastman Spectrum Analysis Film, No. 2.* It has good speed, moderate contrast, and medium resolving power and granularity. Its contrast and wave length characteristics are very uniform throughout the spectral region λ2400A–λ4400A.

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Missing . . .

"Missing in action." You know what that can mean.

Mom says you must be brave. "It's what your father would expect of us," she tells you when it's bedtime and your chin starts to feel shaky. Then she kisses you extra hard and turns her head away so you can't see her eyes.

You've never let her see you cry. Not once, since that telegram came and she twisted it all up in a ball, then smoothed it and put it in the desk.

But, lying in bed, you play "Pretend"—pretend you can hear his step as he comes up to your room—pretend you can feel a stubble brush your forehead. And sometimes, in the dark, you can almost smell a cigarette-y suit close to your face.

Later you dream—dreams that you don't tell about. And in the morning you wake up with that funny, empty feeling in your stomach.

* * *

Poor little guy. We—all of us—wish there were something we could do. Perhaps there is. Why shouldn't it be this?

We can resolve that the plans your father had for you shall remain within your reach, that you shall have the chance to grow and learn, that your opportunities will be bounded only by your own get-up-and-go, that you will progress and prosper in direct relation to your own ability—in a land of freedom and opportunity.

Those are the things your Dad valued, the things for which he gave his life. Though some may strive to change all that—provide you with the "benefits" of an all-powerful government, the "advantages" of regimentation, the "blessings" of bureaucracy—we can resolve they won't succeed.

* * *

You, son, won't read these words, and if you did, they wouldn't mean much to you now. But your father's friends—known and unknown—are making you a promise, just the same.

You may never hear it from their lips. But if you were older you would read it in their faces—recognize it in their spirit. They are determined to keep America free. To keep it a land in which government is the servant, not the master of the people. To keep it the kind of America your Dad wanted to preserve—for you.

CHESAPEAKE AND OHIO RAILWAY

CLEVELAND, OHIO

THE SEARCH THAT NEVER ENDS

IN THE industrial life of America, research has been of constantly increasing importance. And today it is a national resource, for the research of industrial and college laboratories is proving its value in War.

To the Bell System, research is an old idea, for the telephone itself was born in a laboratory. Behind its invention, sixty-nine years ago, were researches in electricity and acoustics and in speech and hearing.

And, ever since, there has been a laboratory where scientists have searched to know more about these subjects; and with their associated engineers have applied the new knowledge, fitting it with all the old, to make the telephone better and better.

Their fields of inquiry have broadened and deepened through these years; they inquire into all the sciences and engineering arts which have any promise of improving the telephone. Much has been learned but still more will be, because their search goes on. That is why the telephone laboratory grew to be Bell Telephone Laboratories, Incorporated, the largest industrial laboratory in the world. And it exists to improve telephone service.

Improvements in industry can be left to chance in the hope that some one, sometime, will think of something useful; that some good invention will turn up.

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